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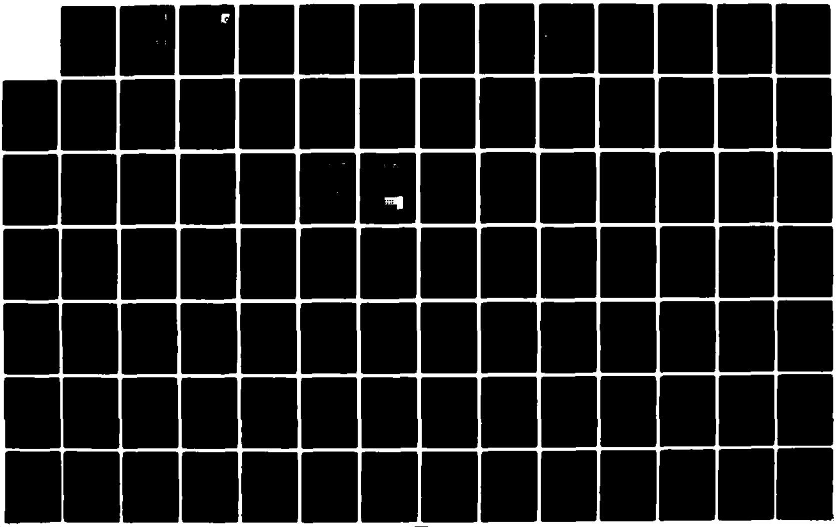

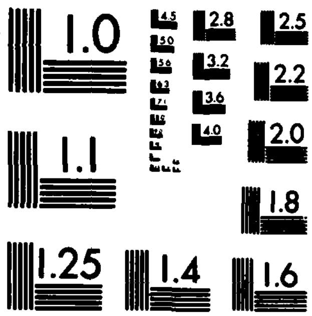

MICROCOPY RESOLUTION TEST CHART
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PROCEEDINGS OF THE DOD COMBINED ENVIRONMENT RELIABILITY TEST (CERT) WORKSHOP 2 - 4 JUNE 1981

UNIVERSAL TECHNOLOGY CORPORATION

January 1983

Approved for public release, distribution unlimited

FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

NOTICE

This technical report has been reviewed and is approved for publication.

Alan Burkhard

Alan H. Burkhard, Technical Manager
Combined Environments Test Group
Environmental Control Branch

FOR THE COMMANDER

Solomon R. Metres

Solomon R. Metres, Director
Vehicle Equipment Division

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A DOD workshop was held 2-4 June 1981 at Atlanta, Georgia. Seventy-six representatives from industry and government attended the workshop. The workshop addressed the cost and technical effectiveness of Combined Enviornment Reliability Testing (CERT), need for Environmental hardware engineers, need for government CERT facilities and the blending of MIL-STD-781 and MIL-STD-810. Technical papers on recent DOD CERT experience were also presented. In general, it was found that CERT was ready for

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implementation, there is a need for government Environmental Hardware engineers and CERT facilities and MIL-STD-810 and MIL-STD-781 environmental criteria should complement each other.

FOREWORD

This Report was prepared for the PRAM Program Office, Aeronautical Systems Division (AFSC), Wright-Patterson AFB, to record the proceedings of the DoD Combined Environment Reliability Test (CERT) Workshop by The Analytic Sciences Corporation and Universal Technology Corporation under Contract F33657-80-C-0255. The proceedings document contains summaries or written versions of presentations and working group discussions. The Workshop findings, issues and recommendations are summarized in an Executive Summary at the beginning of the Report.

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EXECUTIVE SUMMARY

The DoD CERT Workshop was held 2-4 June 1981 at the Presidential Hotel in Atlanta, Georgia. Seventy-six representatives from industry and government attended the workshop. The purpose was to develop recommendations concerning the use of CERT in the acquisition process. A summary of the issues and recommendations is presented below. Section IV of this document contains a more detailed description of the discussion, issues and recommendations of the working groups.

A. CERT MANAGEMENT/COST EFFECTIVENESS/DOD 5000.40 WORKING GROUP

Issue #1:

Educate the aerospace community on the uses of CERT and results of the workshop.

Recommendation: In addition to the proceedings, a presentation should be prepared and presented to appropriate organizations, such as HQ AF Systems Command and Joint Logistics Commands. Also, presentations can be made to different engineering conferences and symposia as well.

Issue #2:

Identify the most effective means of implementing the use of combined environments testing in acquisition and modification programs throughout the DoD.

Recommendation: A dual approach was recommended: top-down and bottom-up. It was recommended that DoD issue a letter to each of the three services requesting identification of a focal point. Also, provide data from programs successfully implementing the combined environments testing concepts (i.e. Common Strategic Doppler, Sparrow Missile, Omega) be consolidated and publicized.

Issue #3:

DoD Directive 5000.40 Implementation Experience.

Recommendation: DoD Directive 5000.40 was formally issued eleven months ago. Since then, DoD is considering revisions to the entire system acquisition process. Therefore, no recommendations were made.

Issue #4:

Need for Environmental Hardware Engineer.

Recommendation: The consensus was that this technical discipline would be greatly beneficial to a System Program Office in developing test criteria.

Issue #5:

Identification of CERT Benefits.

Recommendation: Combined environment testing is an improved approach to testing. By combining environmental stresses, this would lead to a reduction in the number of tests and equipment items required for testing. Also, by more closely simulating operational environments, a better measure of field reliability can be obtained. (See Section IV, Figure 3)

3. TECHNICAL APPLICATIONS WORKING GROUP

Issue #1:

The potential uses of CERT.

Recommendation: CERT should be based upon thorough, realistic engineering analysis. It is applicable in any situation in which it can improve effectiveness or efficiency. Test criteria should be developed for each test and application, and should not be applied as a blanket methodology.

Issue #2:

Use of CERT in lieu of, or conjunction with, flight testing.

Recommendation: While CERT should not be considered as a complete replacement for flight testing, it can be used as a pre-flight test design and screen. It was also suggested that CERT should be used at as great a level of assembly as feasible.

Issue #3:

Use of CERT for multi-application equipment.

Recommendation: The most severe environment, including the life cycles of a multiple platform or mission, should be used as a baseline in establishing a test environment on design improvement.

Issue #4:

Differences, if any, between reliability tests for operational and compliance characterization.

Recommendation: Representative environmental test profiles should use realistic stresses. User's needs should determine which test profiles are considered representative for operational versus compliance characterization.

Issue #5:

Use of CERT as a substitute for, or in conjunction with, other tests.

Recommendation: CERT should be used as a method to replace test time and costs in terms of combining test objectives, such as environmental qualification, reliability improvement, etc.

C. FACILITIES WORKING GROUP

Issue #1:

Availability of a government-owned and operated CERT facility.

Recommendation: It is recommended that both industry and government have CERT facilities. Government facilities should be used to develop test techniques and specifications, assure impartial evaluation of competing contractors, and assess product reliability. Contractor facilities should be used to design, evaluate, and correct deficiencies of systems, especially in early development.

D. MIL-STD-781/APPENDIX B AND MIL-STD-810 WORKING GROUP

Issue #1:

Differences between the two standards.

Recommendation: MIL-STD-810 is used as a high level test criteria to determine whether equipment will function and withstand severe environmental conditions for particular positions in the life cycle profile. It is a short duration test. MIL-STD-781/Appendix B should be used to represent those levels which are found for the majority of the life cycle to obtain reliability (i.e. MTBF) information. It is a long duration test.

Issue #2:

Environmental Data Base.

Recommendation: A focal point should be established to maintain a readily available document which contains a common environmental data base of existing platforms.

Issue #3:

Establish minimum vibration level for retaining test effectiveness.

Recommendation: Delete the requirement to vibrate during the test time when the mission profile vibration level is equal to or less than 0.001 g^2/Hz.

Issue #4:

Research and development plan for MIL-STD-781 and MIL-STD-810.

Recommendation: Establish a five-year research and development plan to obtain and evaluate improved methods, procedures and techniques.

SECTION I - OVERVIEW

WORKSHOP INTRODUCTION

A. Purpose

The purpose of these proceedings is to document the results of the DoD CERT Workshop conducted on 2-4 June 1981 in Atlanta, Georgia. The DoD CERT Workshop was held to develop recommendations concerning the use of CERT in the acquisition process. These recommendations covered the cost-effectiveness, applicability and benefits of CERT.

B. Scope

A three-day workshop was conducted to address the issues and applications of CERT testing. An outline of the Workshop Agenda is included on pages 1.1.3 and 1.1.4. The keynote address, given by Brigadier General Elbert Harbour, stated the purpose of the workshop. Key members of government and industry participated in a distinguished panel forum which gave a management's perspective in the area of acquiring reliable weapon systems and the effect which reliability testing can have on these systems. Several technical papers were given which presented the many different viewpoints and assumptions which have evolved from the use of CERT. This was done to achieve a common ground for the participants.

The workshop discussion sessions consisted of four working groups: CERT Management/Cost Effectiveness; Technical Applications; Facilities; and, MIL-STD-781 and MIL-STD-810. Each group was given specific issues to address. The final outout of the groups were recommendations which will impact DoD policy on combined environment testing.

C. Background

Over the past six years, there has been an intensive effort to improve the nature and quality of environmental and reliability testing. Many of

these testing methods have been labeled "CERT". This has led to the acronym CERT becoming a generic term for any kind of environmentally-based testing in which realistic usage environments are combined in a practical manner and varied as a function of time. The growing universal usage of this acronym has led to many misconceptions as to what is practical and cost-effective in any given situation.

The DoD CERT Worshop was conceived to focus on the identification of what has been found to be practical, useful and cost-effective. Results from extensive government and industry experience in the use of CERT would be presented. These experiences would be used to develop recommendations from the workshop which could serve as a guide to future acquisitions. The output of this workshop is to be given the widest possible distribution to policy makers, project engineers and test practitioners to serve as a consolidated assessment of where, when and who should be doing CERT.

CERT WORKSHOP AGENDA

Monday, 1 June 1981

1800-2100	Pre-Registration

Tuesday, 2 June 1981

0800-0900	Final Registration
0900-0930	Welcoming Address
0930-1000	Distinguished Panel Forum
1000-1015	Refreshment Break
1015-1115	Distinguished Panel Forum (continued)
1115-1130	Question/Answer Period
1130-1300	Group Luncheon
1300-1500	Selected Technical Papers (4 speakers)
1500-1520	Refreshment Break
1520-1700	Selected Technical Papers (3 speakers)
1700	Adjourn

Wednesday, 3 June 1981

0830-0900	Assignments/Instructions for Working Group Sessions
0900-1200	Working Group Sessions 1. CERT Management/Cost Effectiveness/DOD 5000.40 2. Technical Applications - Advances in Techniques 3. Facilities (In-House vs Industry) - Current Capabilities 4. MIL-STD-781/Appendix B & MIL-STD-810 Proposals
1200-1330	Group Luncheon
1330-1700	Working Group Sessions (continued)
1700	Adjourn

Thursday, 4 June 1981

0830-1000	Wrap-up of Working Group Sessions/Reports
1000-1015	Refreshment Break
1015-1115	General Session on Working Group Reports (15 min. summary of each)
1115-1130	Closing Remarks
1130	Adjourn

"CERT" - COMBINED ENVIRONMENT RELIABILITY TESTING

Brigadier General Elbert E. Harbour
Deputy for Airlift & Trainer Systems
Aeronautical Systems Division
Wright-Patterson AFB, Ohio

It is my pleasure to be given the opportunity to say a few words about Combined Environment Reliability Testing (CERT). During the next few minutes I would like to concentrate on three issues. First, "Is reliability of a weapon system important?" Secondly, "How much reliability should a weapon system have?" Third, "Can reliability be predicted accurately?"

To begin, let's look at a little history regarding the weapon system called the flying machine. Contrary to popular opinion, the government's first contract to buy a flying machine was not with Orville and Wilbur Wright. Well before the Wright's first flight, the War Department's Board of Ordnance and Fortification secretly allocated $50,000 to Dr. Samuel P. Langley, who was subsequently unable to produce a promised flying machine. When this information became generally known, both Congress and the Press had been extremely critical of this so-called wastage of public funds. As a result, the Board of Ordnance and Fortification declined to enter into negotiations with the Wright brothers until a machine was produced, which, by actual operation was shown to be able to produce horizontal flight and to carry an operator.

However, this fly-before-buy program with the Wright Brothers, had by today's standard a serious shortcoming in that there were no CERT or reliability demonstration requirements, only performance requirements. The airplane development program was apparently run under the belief that there is a time and place for everything and the Wright flying machine was not the time nor place for CERT. If that is the case, the question is then, "should there have been?"

The answer to this question is rather obvious, especially if you want to remove the uncertainty about our capability to successfully conduct military actions. We must know the reliability of our weapon systems; this in turn drives force size. Take for example a cannon equipped aircraft, say similar to the A-10. If this aircraft had a kill accuracy of .2 and a reliability factor of .2, together the cannon equipped aircraft would have a kill probability of .04. Hence, in order to assume a 50 percent per day kill on 1,000 targets, we would need 12,500 aircraft sorties per day. In the above example, there is a strong indication that both performance (accuracy) and reliability are candidates for improvement. The above example makes a clear case for reliability. But how much is the question.

The answer to the second question on how much reliability is far more complex. Perhaps there are no standard answers. Another example. Let's suppose that $70 billion up-front R&D cost will drive reliability of our cannon equipped weapon system up to the point that the lowest life cycle cost is achieved. Is $70 billion affordable? Seventy billion dollars will consume the entire Air Force budget. How can we pay, feed and train the crews? This is about the point where some would lose sight of the objective and raise the question "Is the cannon equipped aircraft affordable?", but is a separate issue. What we really do is make a subjective tradeoff. We must look at reliability projected cost curves and pick a point, a reasonable point.

Now for the third issue, "Can reliability really be predicted?" There are those experts who say that laboratory reliability demonstrations can predict reliability and there are those experts that say the laboratory cannot simulate field conditions. I have also been advised by reliability experts that there is a definite correlation between the laboratory reliability demonstration and field experience, but that this relationship varies from system to system and they, the experts, don't know how to predict that relationship.

I don't intend to get embroiled in that issue but I am sure that we do know how to design-in reliability, how to predict and measure stress

points during initial design of the system and how to continue this method throughout development of a system. So rather than argue about how many teeth a horse can have, like the earlier philosopher, let's just count the horse's teeth and get on with CERT.

But CERT, I believe, must be subjected to the same scrutiny and logic in arriving at how much is enough, which we currently do in determining how much reliability is enough. Theoretically, we could build a statistically significant number of our cannon-equipped weapon systems and conduct CERT on them until the desired reliability was achieved. At this point, production could begin with confidence. But, this isn't practical.

On the other hand, some environment and reliability testing is essential. This reminds me of the story of an old friend of mine. My friend is a farmer and he was approached by a city slicker one day. The city slicker wanted to buy the farmer's old plow horse. Now this horse was not in the best of health -- and the farmer knew it. But the city slicker wanted a horse and offered the farmer $100. The farmer really tried to caution the city slicker on the horse's health, but the city slicker's mind was made up. The $100 changed hands and the city slicker had himself a horse. You will notice that no CERT was performed, not even a ride-before-buy.

A couple of weeks passed and the farmer saw the city slicker in town. The city slicker told him that the horse had died just after he got it home. The farmer said he was sorry but that there was no way he could give back the money - he had already spent it. The city slicker stated that he didn't want his money back; in fact, he said he had made $1000 off of the horse. The farmer asked, "How in the world did you make $1000 off of a dead horse?" The city slicker said that he had a raffle and sold 1000 tickets for $1 apiece. The 1000 people must have really been upset, the farmer said, when they found out that the horse was dead. No, said the city slicker, only one - - and I gave him his dollar back! Unlike the city slicker, we can't get our dollars back if we buy a dead horse. While CERT won't keep us from the purchase, it certainly will provide insight as to our horse's longevity.

CERT is important and is a must when the performance technology is in hand. The C-X is a prime example. THe C-X technology is not only in hand but has been demonstrated by the commercial fleet. When we started the C-X we did not call our approach CERT, but rather environmental stress screening (ESS). ESS testing is designed to stimulate failures by applying random vibration and temperature cycling to all of the electronic equipment. The purpose of the screening is to identify weak parts, workmanship defects and other anomalies and to remove them from the equipment prior to building the subsystem, and finally the system.

In closing, let me caution you. Although CERT is an approach whose time has come, it must be instituted with sound judgment. Keep the objective clearly in mind concerning what is practical and cost effective in your own particular situation; and lastly, do not become a cult that has lost sight of the objective. If you lose sight of the objective, doubling the effort is futile. A comprehensive reliability program must be established and conducted which will satisfy the reliability requirements contained in the specifications. The bottom line is to design for reliability, but work with the developers and prove that you have a better mousetrap and the developers will beat a path to your door. Finally, remember if you do try to force CERT upon the developer's world, it will not work, because there are more of the developers than there are of you.

SECTION II - DISTINGUISHED PANEL FORUM

INTRODUCTION

The purpose of the Distinguished Panel Forum was to bring together some of the key leaders of government and industry to present management's perspective on the affects of reliability testing. Each panel member was invited based on his widely recognized expertise and experience in the area of acquiring reliable weapon systems. The panel membership consisted of the following individuals:

Panel Moderator:

Colonel Robert Lopina
Deputy for Engineering
Aeronautical Systems Division

Panel Members/Speakers:

Colonel Thomas Musson
Asst for Reliability and Maintainability
Office of Under-Secretary of Defense
for Research and Engineering

Mr. Robert Brown
Asst to the Commander
Hq Acquisition Logistics
Division

Mr. Robert Hancock
Manager of Combined Environments
Technology and Test Organization
Vought Corporation
1979-80 National Institute of
Environmental Sciences President

Mr. Jack Lavery
Asst for Product Assurance
Hq Air Force Systems Command

Summaries of the presentations by these four speakers are included in the following pages.

SUMMARY OF PRESENTATION
by
Robert V. Brown
Assistant to the Commander
Air Force Acquisition Logistics Division
Wright-Patterson AFB, Ohio

Mr. Brown began by defining the AFALD role as one of ombudsman for the maintainers and users of systems and equipment. He indicated that more accurate methods of predicting field reliability are sorely needed. In the absence of such better methods, his standard guidance within the AFALD for logistics planners has been that the development community's reliability predictions should be lowered by factors as high as 10.

Brown indicated that performance over time in a statistically significant sense differentiates CERT from CET, and that the "fix" in TAF (Test-Analyze-Fix) really means "fix the design" or "redesign", as contrasted to simply restoring a failed unit to operational status. He emphasized that fixing the design (redesigning as required) is one of the most important concerns of today's logisticians. CERT appears very close to being ready for implementation, and he urged the workshop to implement the concept expeditiously. Finally, Mr. Brown closed with several specific challenges to the Workshop:

1. Determine how to measure the operational benefit of reliability.
2. Consider the benefits of faster redesign realized through locating the CERT facilities at contractor's plants.
3. The Military Standards are guides. Are they sufficient in clarity and scope?
4. Find the best way to implement the DoD policy on Reliability Testing.

SUMMARY OF PRESENTATION
by
Jack Lavery
Assistant for Product Assurance
Hq Air Force Systems Command
Andrews AFB, Maryland

Mr. Lavery emphasized that it was time to bring CERT into operational use. CERT should become institutionalized. Mr. Lavery posed a number of challenges for the workshop to address and come up with guidance for senior management. He emphasized objectivity and earning the credibility of management. He recommended a balanced program with tailorability to specific requirements. He further emphasized the need for clear communications with management showing the return on investment.

It was pointed out that there are important programs today which needed CERT, such as the B-1 bomber and the Air Launched Cruise Missile (ALCM). He recommended that the Working Groups come up with guidance for tailoring CERT in the acquisition process. He suggested that we establish the relationship between MIL-STD-781C or MIL-STD-810C and the acquisition process.

Mr. Lavery commented that it was often easier to define an environmental test for a piece of avionics than to identify the mission profile that the avionics would actually see during its life-cycle. A chart was shown (next page) which compared in-field experience with test data for the F-15 avionics.

Mr. Lavery charged the Workshop attendees with coming up with a planned course of action to institutionalize CERT.

F-15 AVIONICS AVAILABILITY STUDY

	AFR 66-1 (1977)	McDONNELL (1979)
INFLIGHT FAILURE INDICATORS	100	100
"CND"	47	43
REPAIR ON EQP	3	21
REMOVALS	50	36
"RTOK"	12	11

SUMMARY OF PRESENTATION
by
Robert Hancock
Manager, Combined Environments Technology
and Test Organization
Vought Corporation
Dallas, Texas

Mr. Hancock summarized for the participants of the DoD CERT Workshop, the position of the Institute of Environmental Sciences (IES) with regards to CERT. There is a need to identify CERT in terms of qualifiers such as platform (aircraft, missile, shipboard,....), environments (temperature, sinusoidal vibration, random vibration, ...), test type (improvement, reliability growth, estimate reliability,...), and hardware level (system, subsystem, component, ...).

IES has been assessing the CERT facility requirements as a result of direction of MIL-STD-781C and DoD Directive 5000.40. Their estimate of required expenditure of $400 million over 10 years (from 1975 to 1985) is currently at $100 million after 5 years, thus at the half-way point only 25% of the necessary funds to facilitate have been expended. The consensus is that industry will put CERT facilities in place when there is justification. There is a need for a "new look" CERT Program Status which would define the role of CERT in the procurement cycle and would be advanced to upper management, perhaps through MIL-STD-XXX.

IES would recommend that the Government:

- Require CERT in validation phase
- Continue CERT in the development phase
- Specify CERT in RFP
- Adopt "new look" document (MIL-STD-XXX).

Copies of Mr. Hancock's viewgraphs are included in the following pages.

IES CONCENSUS ON CERT

TEST METHODS

- NEED CLARIFICATION OF CERT VS. CET (NO RELIABILITY OUTPUT)
- CERT W/L-C PROFILING FOR RELIABILITY GROWTH (TAAF), RELIABILITY DEMO AND RATE
- CET W/L-CP HAS APPLICATIONS FOR DESIGN PROOF TESTING
- CET (WITHOUT PROFILES) FOR EARLY DESIGN STUDIES, DESIGN EVAL AND PROD. SCREENING

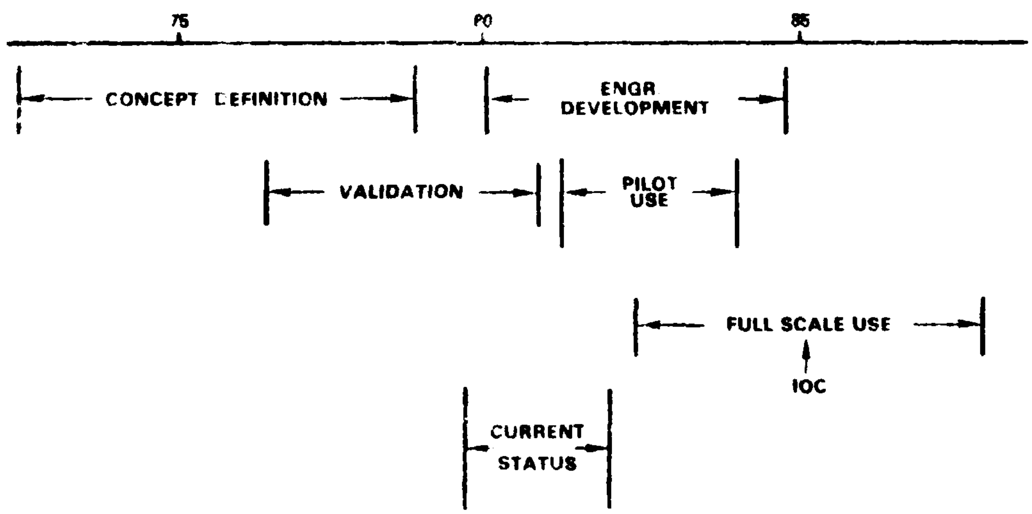
LIFE-CYCLE ENVIRONMENTS

- MAJOR EFFORT NEEDED TO COMPILE TRACEABLE DATA BANK
- CAN SPECIFY TESTS MUCH MORE ACCURATELY THAN DEFINE ENVIRONMENTS

FACILITIES

- WILL PUT IN PLACE WHEN PROCUREMENT PRACTICES ALLOW JUSTIFICATION
- INITIAL 1976 ESTIMATE FOR 781c DEMO — 130 MIL/5 YRS.
- ESTIMATES REVISED TO SATISFY TAAF AND CET SCOPE — 400 MIL/10 YRS.
- SPENT APPROX. $100 M BY 6-80, ½ OF NEEDED RATE FOR 1985 IOC.

NEW-LOOK/CERT OVERALL "PROGRAM" STATUS



NEW-LOOK AND CERT RISK FACTORS (VIEWED AT TIME OF FSD PROPOSAL)

OLD-LOOK	CHARACTERISTIC	NEW-LOOK
1 - 2 HR MTBF	– SYSTEMS RELIABILITY –	6 - 8 HR MTBF (F-18)
INCREASING	– OPS. SUPPORT COSTS –	SHOULD DECREASE
10:1	– LAB. REL. MEAS. DISPARITY –	2:1
METHODS IN PLACE	– RELIABILITY PREDICTIONS –	NO DATA BASE
METHODS IN PLACE	– L-C COSTING –	NO DIRECT BENEFIT FACTORS
KNOWN	– TEST (& DESIGN) REQM'TS –	TAILORED/UN-CERTAIN
IN PLACE	– TEST EQUIPMENT –	UNCERTAIN INVESTMENT
KNOWN	– LAB TESTING COSTS –	FEARED MUCH GREATER
SPARES, ECP'S	– CONTRACT REWARDS –	NO OBVIOUS BENEFITS
DEFINITIVE	– SPEC PHILOSOPHY –	PERFORMANCE
BUSINESS AS USUAL	– ENGR. APPROACH –	INNOVATIVE
	"COMMUNITY" ATTITUDES	
TEST ONLY	– TEST LAB FUNCTION –	RDT&E
SMALL, INDEPENDENT	– TEST LAB SIZE –	LARGE
STATISTICS, COSTING, SCH.	– PERSONNEL BACKGROUNDS –	ENGR. PHYSICS, TEST
PMO		TEST EQ. MFG'RS

"MANAGEMENT" ASSESSMENT

- CONTINUE CERT PROGRAM DEVELOPMENT
- SPECIFY USE OF CERT AND NEW-LOOK IN RFP'S AND CONTRACTS
- START REQUIRING SOME RELIABILITY GROWTH W/CERT IN VALIDATION
- ADOPT A TOP DOCUMENT ON "NEW-LOOK" MANAGEMENT
- WOULD LIKE TO SEE "NEW-LOOK" DEVELOPMENT PLAN

SUMMARY OF PRESENTATION
by
Colonel Thomas Musson
Office of Under-Secretary of Defense/Research and Engineering
Department of Defense
The Pentagon/Washington, DC

Colonel Musson addressed the Workshop concerning the Department of Defense perspective on CERT as reflected in DOD Directive 5000.40, and more recently, in the recommendations of Mr. Frank Carlucci. He emphasized the need to understand the life profile of a system, to define the environmental conditions and influence the design accordingly to do CERT, and to use laboratory test data for R&M estimates only to the degree that the use environment is represented in the test. Reliability test objectives are to: (1) identify deficiencies; (2) provide realistic R&M measures for users of the system; and (3) determine contractor compliance with R&M requirements. The tests defined in MIL-STD-785B were discussed relative to these objectives.

Colonel Musson concluded his remarks with a discussion of his personal opinion concerning the factors which influence system reliability (design, parts, workmanship, operational concept and environment, maintenance concept and environment) and the relevance of testing in the different phases of the system life-cycle to these factors.

Copies of the presentation viewgraphs are included in the following pages.

DoD DIR. 5000.40 R&M POLICY

- ESTABLISH APPROPRIATE R&M REQUIREMENTS FOR EACH ITEM, BASED ON A DEFINED ITEM LIFE PROFILE THAT INCLUDES ENVIRONMENTAL STRESSES AND THE SKILL LEVELS OF OPERATOR AND MAINTENANCE PERSONNEL
- TEST CONDITIONS AND PROCEDURES SHALL BE OPERATIONALLY REALISTIC, AND THEY SHALL BE DEFINED EARLY ENOUGH TO INFLUENCE ITEM DESIGN
- PERFORMANCE, RELIABILITY, AND ENVIRONMENTAL STRESS TESTING SHALL BE COMBINED, AND TYPES OF ENVIRONMENTAL STRESS WILL BE COMBINED INSOFAR AS PRACTICAL
- IN EVERY CASE, MEASURED TEST RESULTS SHALL BE CONSIDERED VALID R&M INFORMATION ONLY TO THE DEGREE THAT THE TEST CONDITIONS AND PROCEDURES SIMULATE THE OPERATIONAL LIFE OF A PRODUCTION ITEM

OBJECTIVES OF RELIABILITY TESTING

- DISCLOSE DEFICIENCIES IN ITEM DESIGN, MATERIEL AND WORKMANSHIP
- PROVIDE MEASURED RELIABILITY DATA AS INPUT FOR ESTIMATES OF OPERATIONAL READINESS, MISSION SUCCESS, MAINTENANCE MANPOWER COST AND LOGISTICS SUPPORT COST
- DETERMINE COMPLIANCE WITH QUANTITATIVE RELIABILITY REQUIREMENTS

TEST REALISM MIL-STD-785B

- A TEST THAT ONLY DISCLOSES A SMALL FRACTION OF THE OPERATIONAL FAILURES IT IS SUPPOSED TO DISCLOSE IS A WASTE OF TIME AND RESOURCES
- A TEST THAT INDUCES FAILURES WHICH WILL NOT OCCUR IN SERVICE, FORCES UNNECESSARY EXPENDITURES OF TIME AND RESOURCES TO CORRECT THOSE FAILURES
- THE DEGREE TO WHICH ANY RELIABILITY TEST MUST SIMULATE FIELD SERVICE DEPENDS ON THE PURPOSE OF THE TEST

MIL-STD-785B
TEST PROGRAM

RELIABILITY ENGINEERING TESTS

TASK 301 ENVIRONMENTAL STRESS SCREENING (ESS)

TASK 302 RELIABILITY DEVELOPMENT/GROWTH TEST (RDGT)

RELIABILITY ACCOUNTING TESTS

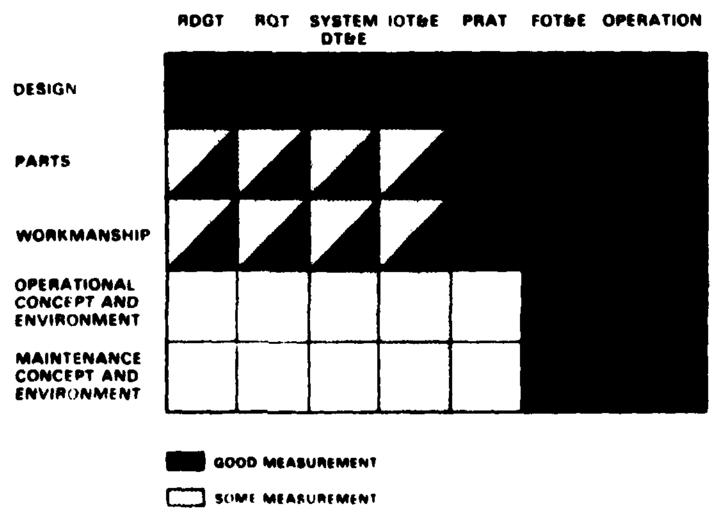
TASK 303 RELIABILITY QUALIFICATION TEST (RQT)

TASK 304 PRODUCTION RELIABILITY ACCEPTANCE TEST (PRAT)

MIL-STD-785B TEST PROGRAM

TASK	TEST	APPROACH	ENVIRONMENTS IN	
301	ESS	STIMULATE	SERIES	VARIOUS LEVELS OF ASSEMBLY
302	RDGT	STIMULATE/ SIMULATE	SERIES/ COMBINED	
303	RQT	SIMULATE	COMBINED	
304	PRAT	SIMULATE	COMBINED	SAMPLING

RELIABILITY IN THE TOTAL TEST PROGRAM



SECTION III - GENERAL TECHNICAL SESSION

RETHINKING CERT: A REALISTIC PERSPECTIVE

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A Technological Orphan

Combined environment testing is not new; tests using combinations of a variety of forcing functions have been used for decades. In 1975, the Air Force Flight Dynamics Laboratory at Wright-Patterson AFB introduced the concept of accurately combining measured flight environmental conditions for mission profile testing in the laboratory to the technical community at large. (Ref. 1). This method was called CERT, for Combined Environment Reliability Testing. Since that time, numerous studies have been made and reports distributed. CERT methodology for mission profile testing was included in MIL-STD-781C (Ref. 2) nearly four years ago and is recognized in current DoD policy (Ref. 3). The draft versions of MIL-STD-810D and MIL-STD-781D both include combined environment testing.

Yet, in spite of constant and widespread exposure, combined with official DoD recognition, CERT has still not achieved anything resembling consistent or enthusiastic acceptance. There is no agreed upon approach to the systematic application of CERT methodology. Even the effectiveness and benefits of CERT remain unresolved within the same community of professionals that promoted the development of CERT more than six years ago.

In the interest of establishing a direction for dealing with these circumstances, this paper:

1. Analyzes the underlying causes of the ambivalent attitude shown CERT to date.

2. Objectively evaluates the potential benefits and limitations of CERT.

3. Recommends several logical approaches to CERT application.

CERT is a Four-Letter Word

Certain four-letter words have acquired a special notoriety because of their dual identities. They not only serve as labels for objects or actions, but also evoke strong emotional reactions based on personal sensitivities and background.

In referring to CERT as a four-letter word, I do not mean to imply a value judgment of any kind regarding CERT's acceptability or value. However, CERT too, is characterized (unfortunately to its disadvantage) by a similar dual identity. On the one hand, CERT serves simply as a label for a technological tool. On the other hand, CERT seems to have the ability to trigger strong subjective responses at its mention. It is quite possible that these reactions are an attempt to fill the judgmental vacuum left by the professional community. But regardless of the reason for these emotional reactions, they only serve to further cloud the issue of CERT validity.

In the following discussion, I would like to distinguish between the objective and subjective identities of CERT and treat each separately. First, let's consider CERT as a label.

CERT Defined

I would like to recommend adoption of the following definition of CERT:

"Any laboratory test for hardware reliability improvement or characterization* in which environmental forcing functions are applied simultaneously."

This straightforward definition is free from any suggestion of program phase, contractual motivation, specific methodology, or facility sophistication. It allows CERT to be viewed objectively as just another tool available to the test designer for hardware development. As such, it provides a logical starting point from which to begin a CERT evaluation.

CERT Myths

Before discussing what CERT is, it is important to first clarify what it is not. Certain myths concerning CERT often seem to be treated as facts in CERT debates. These myths have not been deliberately perpetrated by any specific individual or organization. Rather, they seem to result from incomplete communications. Nevertheless, the result is that many arguments advanced both for and against CERT are without credible foundation. Several of these myths are briefly described below.

Myth No. 1: CERT is limited to certain forcing functions.

With the definition recommended above as a basis, there is obviously no limitation placed upon forcing function types or numbers by the CERT concept. Such terms as "Full-CERT" and "CERT-Without (a given forcing function)" only tend to limit CERT's potential uses by implying the existence of an "official" baseline combination of forcing functions.

Note: *The provision of measured reliability data as input for estimates of operational readiness, mission success, maintenance manpower cost and logistics support cost (Ref. 15).

Myth No. 2: CERT = Mission Profile Testing.

While mission profile testing is undeniably a major subset of CERT, it is wrong to assume that no other forms of CERT exist. For example, CERT may be used quite effectively for stress screening by tailoring the forcing functions to specific defect modes or hardware characteristics (Ref. 4), regardless of mission forcing function profiles. To evaluate its full utility, then, CERT must be considered in all of its possible manifestations and not artificially limited to one specific methodology.

Myth No. 3: CERT makes troubleshooting and failure difficult.

Some have taken the position that troubleshooting and failure analysis are made more difficult when more than one environmental forcing function is applied at a time. However, actual CERT users' experience (Ref. 5) has shown no such difficulty, with troubleshooting being accomplished by normal means while *removing or using one forcing function* at a time. Established failure analysis techniques still provide information useful in determining appropriate corrective action. Once a corrective action has been identified, the specific environmental forcing function responsible for the failure becomes academic.

Myth No. 4: CERT facilities are too expensive.

This is a common assertion, apparently based on the mistaken assumption that certain complex experimental facilities are representative of the way all CERT facilities must be. While it is true that it will cost more to combine and tailor some forcing functions than others, this cost is only too expensive when the test benefits are not commensurate with the facility expense. In fact, expensive testing (as related to test benefits) is really the consequence of administrative and regulatory policies which rigidly and unnecessarily constrain its use. CERT doesn't have to be

prohibitively expensive, but it is all too often artificially driven to be so by those assuming the previously stated myths to be fact.

Myth No. 5: CERT facilities are few and far between.

Combined environment test facilities have been in use for decades. In the past several years, many companies and government organizations have purchased or developed CERT facilities with extensive mission profile test capabilities. Some of these have been purchased directly from commercial facility vendors while others have been developed from scratch or from modified existing facilities by the organization's own personnel. Forcing function types and control options span a broad range. The main point is that CERT facilities are no longer the laboratory curiosity they once were. They are used routinely by a growing number of organizations for a wide variety of hardware development and acquisition purposes (Refs. 6,7,8,9). This expanding facilities base can serve as a source of valuable CERT experience.

A Multi-Variable Experiment

CERT's existence to date as a mission profile test methodology can best be described as an uncontrolled experiment. The differences between mission profile CERT and traditional environmental tests go far beyond the simple combination of standardized single-environment forcing functions. Mission profile CERT in reality has been an experiment in which several variables have been changed at once, thereby complicating analysis of the experimental results. To date, this experiment has introduced the following variables:

1. Forcing Function Combination: Forcing functions applied in combination instead of sequentially.

2. Tailored Forcing Functions: Forcing function profiles tailored to those expected or measured in actual service, commonly referred to as mission profiles. This contrasts with traditional sequential testing which is normally based upon untailored, standard parameters and methods.

3. Forcing Function Repetition: In mission profile CERT, forcing functions are often repeated for a given number of equivalent missions (cycles). Further, one hardware item is exposed to all forcing function types. Traditional sequential tests, on the other hand, are generally applied only one time, thereby discouraging the full evaluation of cumulative stress effects. In addition, traditional test programs often use several hardware items tested in parallel to different forcing function types. The result is that no single hardware item is exposed to all forcing function types.

4. Scoring: Failure definition (or acknowledgement) ground rules for mission profile CERT and traditional tests have not always been the same (Ref. 10).

The result is that the improved problem disclosure attributed to mission profile CERT could be due to any of these variables, three of which do not involve combining environments.

CERT Utility

To this point, the mechanisms responsible for the potential benefits of CERT do not appear to be well characterized. While this circumstance is certainly not an indictment of the concept, it does present a serious obstacle to its widespread acceptance.

Fortunately, however, there is a much more important, yet commonly overlooked, standard against which to evaluate CERT: efficiency. More

specifically, any problems that can be disclosed by any one of the applied forcing functions will be disclosed by the same test at, in essence, the same time. This is <u>not</u> synergism. Rather, this is parallel tests with different forcing functions applied to the same hardware item. The result is earlier disclosure of problems and, therefore, the best opportunity for accelerated improvement of hardware quality (in effect, accelerated reliability growth). Government and industry experience (Refs. 11,14) has shown that significant time and cost savings can be realized (Figure 1).

TESTS	SAVINGS	
	Dollars	Days
Deleted 7 separate environmental qualification tests	$195,400	129
Deleted reliability demonstration test (5,000 hrs @ $170/hr)	850,000	125
Replaced with a single CERT growth test	230,000	50
Total Savings	$815,400	204

Figure 1. Savings Available Using a CERT Growth Test (Ref. 14)

In this context, then, CERT may be thought of as schedule compression; as if several, normally sequential, single forcing function tests were applied to the same hardware in parallel. The benefits of this schedule compression can be greatest for those hardware development and acquisition phases (engineering development and stress screening) which are often emphasized least in program planning in the drive to ensure that compliance (i.e., qualification, acceptance) test requirements are satisfied. The following section will discuss these benefits at greater length.

The Troublesome "R"

The main source of controversy over CERT seems to be the "R", Reliability. CERT is not a traditional reliability approach and therefore lacks

the statistical pedigree needed for acceptance within some reliability circles. As a result, reactions to CERT within the reliability community have been observed to range from casual indifference to hostile opposition. However, CERT is also valuable for reliability improvement through deficiency disclosure (Ref. 15) and therefore must not be ignored. If a sincere effort is made to carefully and intelligently apply CERT to a representative hardware population, the appropriate statistical characterization will logically follow.

Several key areas in which CERT can be of value to reliability testing merit consideration and are as follows:

1. Growth Testing: The rate at which hardware improvement occurs will be directly influenced by the rate at which problems are disclosed. Combined forcing function tests can disclose these problems faster (see Figure 1) than traditional sequential tests and, therefore, offer great promise for accelerating reliability growth (Ref. 11,14).

2. Reliability Characterization: The potential for test realism using mission profile CERT can be used to improve the accuracy and thus the usefulness of hardware characterization. This improved accuracy should be of particular value in spares and logistics planning. (While not currently a common practice, characterization could be made more efficient by a form of time compression in which only the forcing function levels most likely to disclose problems are applied; benign levels are not used. Correspondence between laboratory and field exposure to these forcing functions could be retained with appropriate correction constants.)

3. Stress Screening: When hundreds or thousands of hardware items are involved, any reduction in the time required to screen each item will be multiplied many times over with potentially enormous dollar savings (Figure 2). Stress screening CERT, tailored to defect type and hardware anatomy (Ref. 4) (as opposed to mission-use environmental profiles) and applied by inexpensive alternative forcing function generators, such as pneumatic vibrators (Ref. 12) and portable temperature enclosures, can provide this time reduction with minimal facility cost penalties.

Vibration Testing in One Axis:

Test setup	45 minutes
Vibration	10 minutes
Performance Check	45 minutes
Total	100 minutes/unit

If performed as a separate test, vibration would add at least 100 minutes/per unit to the overall time required for screening. If a representative production run of 1000 units is assumed, the savings associated with combining environments are:

Screening CERT Time Savings (Assuming 2 shifts/day) $= \frac{(100 \text{ min/unit})(1000 \text{ units})}{(60 \text{ min/hour})(16 \text{ hrs/day})}$

$= 104+$ Days (without parallel test)

Screening CERT Cost Savings (\$25-\$35/hr range) $= \frac{(100 \text{ min/unit})(1000 \text{ units})(\$/\text{hr})}{(60 \text{ min/hr})}$

$= \$41,666$ to $\$58,333$

Assumption 1 - Screening performed on small to moderate size electronics boxes.

Assumption 2 - At least one other environmental forcing function combined with vibration.

Assumption 3 - Environmental forcing function combined with vibration takes at least as long to apply as vibration. In the case of thermal cycling, this is a safe assumption.

Assumption 4 - Only one axis of vibration was assumed. If 2 or 3 orthogonal axes are used, screening time and cost differentials are multiplied by these factors.

Figure 2. Example of Potential Time and Cost-Savings Associated with Stress Screening CERT.

Building on Strength

Key recommendations made early in the Wright-Patterson AFB CERT study program (Ref. 13) are still valid. Unfortunately, fulfillment of these goals in ways supported by widespread concurrence has yet to happen. These recommendations are:

1. Develop a standard method of deriving environmental profiles

2. Balance the engineering benefits of more complete environmental simulation against increased facility complexity and cost

3. Establish a data base for the complete evaluation of CERT

4. Develop a time-accelerated CERT methodology

CERT experiments in industry and government to date have been inconsistently supported and incompletely defined, but have nevertheless produced valuable data. It is now time for the professional community to try to determine what these data are telling us. However, as with any scientific experiment, we must be prepared to accept any legitimate results, even though they may not agree with our original expectations. Otherwise, there is a strong risk of being blind to useful information.

Although not rigorously defined or quantified, there are significant potential benefits to be derived from the systematic application of CERT to hardware development and acquisition. The challenge we now face is to agree upon clearly defined processes for applying CERT to satisfy differing reliability test needs. These processes should allow already existing expertise and facilities to be put to their best use. The talent to achieve this goal is available. However, building on this strength can only take place in an environment characterized by commonality of purpose, technical honesty, and willing cooperation. Providing this combination of environments will be the biggest challenge.

A Closing Observation

Those experienced in environmental testing recognize that a requirement such as "perform a vibration test" provides no usable guidance. A vibration test could use random, sinusoidal, acoustic, continuous or pulsed excitation, and could be based on input-control or response-definition, orthogonal axis or diagonal vector energy input. In short, there is no functional meaning for the term vibration test in the absence of appropriate qualifiers.

CERT as a concept suffers from the same incompleteness of definition. CERT can legitimately exist as a large number of different methodologies and procedures, to the potential confusion of all involved. While the technical characterization of CERT types, benefits and liabilities remains as an important engineering task, the consistency and clarity of our communications on the subject might be aided by the simple expedient of adopting the right clarifiers. Suggested examples include:

1. Growth CERT
2. Qualification CERT
3. Development CERT
4. Stress Screening CERT
5. Mission Profile CERT

While not a solution to the problem at hand, such an approach could remove a number of communication obstacles which will otherwise make the process of arriving at an accepted solution much more arduous than it need be.

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HARDWARE PROGRAM REQUIREMENTS FOR ENVIRONMENTAL ENGINEERING

by

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ABSTRACT

The primary purpose of this paper is to delineate and emphasize the environmental engineering functions that are necessary during a hardware development program to achieve design integrity and operational reliability and readiness. Involvement of environmental engineering functions is shown to be necessary earlier than at the time of environmental testing during a development program if optimum life-cycle costs are to be achieved. Suggestions are made as to what these necessary functions are and at which program phase they should be invoked. A trend of reliability improvement with environmental testing is shown. Seven fundamental types of tests, distinguished as to purpose and type of test, are defined, and their characteristics are summarized. Recommendations are made for incorporating descriptions of the environmental engineering functions in procurement documents and for policing application of the functions by means of contractor-prepared and customer-approved reports at various program phases. The paper draws on recommendations which originated within working groups of the IES, particularly within IES publications by the author. One of those publications in the Journal of Environmental Sciences, in September 1979 (Reference 1), had a title similar to this paper's title, and one on proposed IES Recommended Test Practices was published in the IES Technical Symposium Proceedings in May 1981 (Reference 2).

INTRODUCTION

Results of studies of reliability of avionics by the Department of Defense in the early 1970's placed a great emphasis on the need for more realistic environmental design and testing to improve the survival of equipment in operating environments (See Reference 3 and 4, for example). Conclusions from these and subsequent studies can be paraphrased as follows: "Failure to design and test adequately for realistic operational environments accounts more than any single factor for the failure to achieve desired reliability in military-fielded equipment". While a number of hardware testing procurement documents have been revised to reflect the concern with realistic test environments, a similar emphasis has not been added to program "front end" engineering (which sets the requirements for design and calls out testing methods). This may be attributed to two primary factors which are common to both the organization that designs and produces a system and to the procurement agency: (1) failure to recognize that the environmental engineer normally accesses a program only through a document such as MIL-STD-810, which is not invoked until late in full-scale development, and (2) belief that published documents and/or procurement documents, in general, adequately specify environments for design and test. The latter conflicts with the current requirement in Department of Defense Directive 5000.40 for tailoring procurement documents to the particular piece of equipment. Although some tailoring can be done by environmental specialists within the procurement agency, it is probable that only the designing and producing organization has enough information (such as transfer functions available for larger systems) to permit tailoring of general environments to a particular box at a given location for timely utilization in the program to affect design and test.

DISCUSSION

Phase and Cost Elements of a Program

For procurement of equipment that is to be added to an existing vehicle, it may be possible for the procuring activity to specify levels of environments that are based on measurements from the actual vehicle. However, in the case of the entire vehicle or major component, such as a wing-mounted store, the designing and producing organization is faced with this task. Procurement documents such as MIL-STD-810C only invoke environmental engineering methods during full-scale development. At the time that such documents normally are applied, it is too late in the program to be effective in changing major program decisions, such as choices on location of equipment and basic layout of equipment bays. Such decisions contribute to life-cycle costs and severity of environment. Figure 1 illustrates this point. It was constructed from information that was obtained from a JLC Design-To-Cost Guide (Reference 5). The figure shows that 85 percent of the decisions that affect life-cycle costs are made by the end of system definition. An additional 10 percent of the decisions are made during full scale development. Therefore, it would be highly desirable to affect environmental design (to the extent that it affects life-cycle costs) during the concept studies. In particular, the environmental trade studies of equipment locations and of life-cycle environments should be accomplished prior to DSARC I for maximum effectiveness. The curve in Figure 1 does not imply that the actual work is done prior to the points shown; it indicates only that the decisions which affect what is done are made by times that are shown. As an example, the decision to conduct reliability development tests during full-scale development should be made during concept studies.

Figure 2 which was extracted from Reference 6, provides a point of reference, illustrating the times and elements that are involved in the development of a system. On the bottom of Figure 2, a bar has been added to indicate a typical number of years required to achieve certain phases. The

bar has been added to indicate a typical number of years required to achieve certain phases. The bar also indicates typical contractor activities which relate to environmental and reliability engineering and testing during those phases. This figure illustrates some of the overlap between phases, and the difficulty in defining the exact phase when something should be accomplished on a given program. For any particular program, much greater overlaps may occur. For example, full-scale development may continue until IOC. As indicated on the bottom of the figure, reliability demonstration tests, if required, may continue until long after the system's reliability has been demonstrated, and may even extend well past full-scale production go-ahead, during customer T&E. The activities which are listed on the bottom of the figure illustrate two additional points: (1) reliability goals typically are established in the validation phase at the time of full-scale development proposal (just under the point labeled six years), during which time the basic motivation of the contractor is to pass the validation tests; (2) passing the validation tests requires that the contractor use the limited, available 6.3 money to conduct only those tests which will assure adequate demonstration of concept validation. It would appear then, that if we are to impact decisions that affect life-cycle costs, the procuring activity may need to fund some environmental testing and engineering during the first six years (validation phase) even though it means some duplication if two or more contractors are involved. Such funding may be very effective in lowering life-cycle costs.

Environmental Engineering Functions

It is recognized that recently revised procurement documents such as MIL-STD-785B and MIL-STD-781C (References 7 and 8) enumerate some of the requirements for environmental engineering and testing. It is also understood that MIL-STD-810D (Reference 9), which is currently in the revision stage, will require that some primary engineering efforts precede specified tests. However, none of these documents identifies an "environmental engineering discipline", so they do not clarify the purposes and tasks that are to be accomplished by this discipline; rather the function is treated as a subset of testing or of reliability and maintainability engineering. Although

this may prove satisfactory, an attempt was made in Reference 1 to segregate the environmental engineering discipline for the purpose of defining objectives and tasks that are necessary to accomplish the objectives that are embodied in the "new-look".

If we were to treat environmental engineering as a function that is similar to the reliability function that is established in MIL-STD-785, then the objectives for the environmental engineering function probably would be as given in Table I. Since environments that are generated by the product, particulary in the case of an entire vehicle, affect the surrounding environments, the third technical objective that is listed in Table I would be a necessary part of the environmental engineering discipline. This activity normally is relegated to the manufacturing department, but it is becoming much more relevant to the environmental discipline with the advent of regulations that have been established by the Environmental Protection Agency and the Occupational Safety and Health Administration; recently, the Surgeons General have issued similar regulations for the military services.

Table II lists the functions of the environmental discipline that arise from the objectives that were just established. The first three items (functions in Table I) are roughly in chronological order. The fourth might be in sequence for major procurements, but it may occur first for additions to existing platforms. In any event, information that is obtained during any one of the functions should be examined for possible feedback or input to the other functions. The first four of the functions that are listed in Table II might prove effective if they were presented in current testing standards as necessary prerequisites to defining life-cycle environments for test purposes.

The five primary environmental engineering program functions can be subdivided into engineering work tasks. These are listed in Table III and segregated roughly by major program phase: research, development, testing and evaluation. The first seven of these tasks are necessary prerequisites to testing, and they occur in chronological order. The next seven tasks, which also appear in chronological order, identify seven basically different types

of tests which are described in Reference 2. A given procurement may not require all of those tests. The last four tasks should be accomplished for any given program. They relate primarily to evaluation of effectiveness of the environmental engineering and test functions.

Environmental Testing Functions

Combined Environment Testing is a necessary component of the "new-look". There has been, and will continue to be, an argument as to whether the acronym CERT, for Combined Environment Reliability Testing, or CET, for Combined Environment Testing, should be used to describe the tests. Strictly speaking, only those tests which have a reliability measure output should utilize the term CERT. Therefore, the more general CET has been utilized within the IES. In either case, it is difficult for two people to communicate the definition of the term, because there are so many variables that are necessary for definition of the term. Four sets of those variables are listed in Figure 3. When utilizing either acronym, it is a good idea to select at least one word from each of the columns which are shown in Figure 3 to assure that the speaker and the listener are on common ground. The first column can be expanded almost infinitely by subdividing each of the major platforms. In addition, there is no general agreement on the definition of the terms which are listed in the third and fourth columns. The Institute of Environmental Sciences (IES) is attempting to eliminate this problem by publishing a series of recommended practices which contain glossaries. A fifth column, which describes the level of environment, should be added to this listing. It would contain the following variables: fixed level, mission or life-cycle profile, some idea as to the length of test time. If the two acronyms are defined in accordance with Figure 3, then much unnecessary confusion can be alleviated.

Figure 4 has been extracted from Reference 2 to provide an example of the definitional problem and of one of the solutions preferred by the IES. It depicts a general trend of reliability improvement with environmental testing. The figure identifies seven basic types of environmental tests which are distinguished by their purpose, description of test, and expected benefits and costs. The titles of the tests in Figure 4 are largely self-explanatory. In

Reference 2, the design proof test (that is defined as 2a in Figure 4) was regarded as similar enough to the test that is defined as 2 to bear the same number. In future publications, 2a probably will be renumbered, so that seven tests will be listed. A distinction has been made here between those tests that are regarded as RDT&E and those that are regarded as production type tests. Reliability growth occurs during the first three tests but is not expected to occur during either the design proof test or the reliability demonstration test. The characteristics of these tests are summarized in Table IV. Not all of these tests will be, or should be, required on a given program. Rather, they provide a convenient distinction for discussion purposes. Necessary requirements for all tests are: (1) feed-back on failures during tests and in the field to aid corrections of design, if they are necessary; (2) acceptance testing of all vendor parts prior to incorporation in the test specimen; and (3) burn-in of all specimens to remove infant mortality and manufacturing defects prior to testing.

The characterizations of the various tests that are shown in Table IV reflect the consensus of the IES working group on environmental and reliability testing. The major purpose of each test has been indicated on line 2 of Table IV, and the major beneficiary of the testing operation is noted on line 3.

As stated earlier, the purpose of the IES recommended practice (of Reference 2) is for presentation to management to clarify the role of testing in hardware development programs. An example of a related standard or specification that has previously been published and which describes a portion of each of the tests is given in line 9 of Table IV. Line 13 of the table reflects an attempt to indicate when the test would prove most effective toward reduction of life-cycle costs.

To illustrate the ideas above and to illuminate the concept that peculiar programs do not require all tests, at all assembly levels, with all combinations of environments, a fictitious testing program summary has been prepared in Table V. It would be appropriate to a vehicle such as a cruise missile or a ground-launched missile, but to no system that specifically is in current procurement. The table might be appropriate for inclusion in a system specification which

could be submitted in the concept definition phase of a program, prior to validation. The parts description in Table V is in accordance with MIL-STD-280A. The design evaluation test which is shown on Figure 4 has not been called out separately in Table V, but it has been assumed as a necessary first step under TAAF. There was considerable argument in the IES working group on the appropriateness of the names for the particular tests, the particular combinations of tests, and the types of tests that are shown in Table V. A general consensus evolving from the working group was that each particular test on a given program should be shown to be cost-effective prior to being incorporated at each level of assembly. Table V illustrates the difficulty in defining a given CERT, if indeed one does exist; and it suggests that while the concept of CERT is valid, its application is extremely product-peculiar.

The methodology that is represented in the "new-look" and which is discussed above, represents a change in environmental testing and engineering that has taken 20 years. As a consequence, it is not readily accepted by program managers who are faced with meeting contract front-end costs and schedules. A program administrator who operates under these constraints cannot be extremely interested in reductions of downstream operational support cost. It has been widely assumed that the additional testing and the new methodology that is required with the "new look" would require additional expenditures during the RDT&E program phases. An attempt has been made in Figure 5 to show why this is not necessarily so, and to show that real cost reductions can occur during the RDT&E phases if <u>all</u> of the "new look" tenets are practiced at all levels of system assembly. Figure 5 shows that significant decreases in RDT&E costs should accrue by the time the contractor's systems tests in the field are concluded, because removal of failures at lower assembly levels result in a reduced number of field tests which are much more expensive than laboratory tests. For example, repeating one $20,000 flight test because of a failed component could easily fund laboratory reliability growth testing for several months. "New look" methodology should result in a substantial reduction of the cost of ownership as shown by the upper curve. One reason for this reduction is that the large expense of performing engineering investigations and corrective actions during operational deployment are replaced by less expensive tests at the contractor's facilities in the laboratory prior to delivery.

Figure 5 is conceptual in nature and could benefit by substantiation with facts that are traceable to existing programs. However, on the basis of the information presented, it is thought that people who propose conversion to "new look" methodology should assimilate the concepts that are reflected in Figure 5, and attempt to sell the "new look" methodology to procuring activities on that basis. The alternative, which may prove quicker and more efficient in the long run, is to institutionalize the methodology within the military standards and specifications that are utilized in procurement. The danger in the institutionalization, to be avoided if possible, is the conflict with tailorability.

CONCLUSIONS AND RECOMMENDATIONS

While the concept that a new discipline called Environmental Engineering is desirable has been presented in this paper, such a defined discipline does not exist. It is thought that published guidelines for practice of the function would be most helpful toward achieving objectives of readiness, reliability, and availability of field hardware. The IES has such a document entitled "Environmental Engineering Management" in preparation, and expects to release it in May 1982. A recommended practices document entitled "Environmental Test Program Management" (Reference 2) should be released in September 1981. It is probable that the IES will continue to encourage the initiation of a specialized discipline aimed at the objectives described above in colleges, government and industry. The question of whether or not an Environmental Engineering Program Management standard, similar to MIL-STD-785, should be issued is still troublesome, primarily from the standpoint of the conflict between institutionalization and tailoring. However, invocation of the necessary environmental engineering tasks early in hardware development programs is essential for the effective achievement of reliability through design, rather than assessment of reliability through tests.

Current recommendations with respect to the environmental engineering functions may be summarized as follows:

1. Procurement documents should reflect guidelines for program environmental engineering. These could take the form of industry standards such as the Environmental Engineering Management Practice to be published by the IES (Reference 2). Another form could be a new Department of Defense pamphlet or other guideline-document which lists environmental engineering requirements and tasks. Those task descriptions might be similar to the descriptions in the current MIL-STD-785B.

2. Procuring agency enforcement of necessary front-end environmental emphasis should be accomplished via preparation of specific reports by contractors for approval by the procurement agency prior to proceeding at such points in the program as the following:

   a. Environmental Program Plan--prior to validation.
   b. Environmental Profile Report--early in validation.
   c. Environmental Design and Test Criteria Report--during validation.

   d. Environmental Test Plans and Report--during full scale development.

   e. Operational Environmental Validation Measurement Report--prior to DSARC IIIA.

3. Procurement documents such as MIL-STDs 785, 781 and 810 should enumerate certain environmental functions as being necessary prerequisites to testing (such as the functions which have been proposed for inclusion in MIL-STD-810D), and which are listed in Table II.

4 Procurement agencies should seriously review the timeliness of environmental engineering tasks and environmental tests, which should cause them to give serious consideration to specifying certain reliability development tests during the validation phase, even though such tests may be duplicated by competing contractors.

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BIOGRAPHY

R. N. Hancock is immediate past president of the Institute of Environmental Sciences (IES). He is active in a number if IES functions, including the Product Reliability Division, which he was instrumental in establishing in 1975. He received a BSME from Texas Tech. in 1953, has spent the major part of his career in environmental engineering and testing, and is currently Manager of Combined Environments Technology for Vought Corporation, in Dallas, Texas. He has published widely, particularly in the field of vibrations and acoustics, and has been active in the Aerospace Industries Association, the Acoustical Society, and on various working groups of the American National Standards Institute.

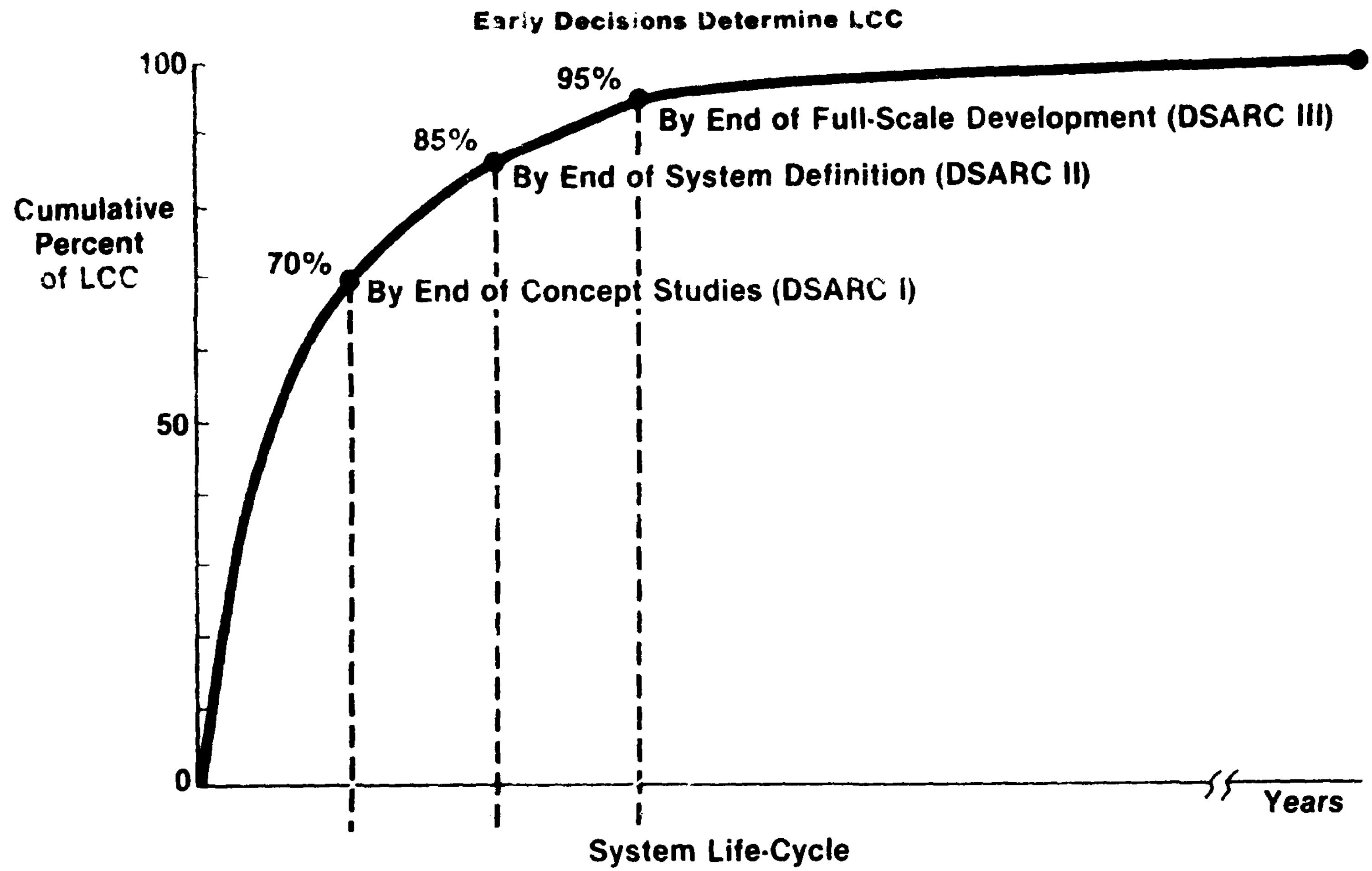

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Figure 1: Effects of Early Program Decisions on Life-Cycle-Costs

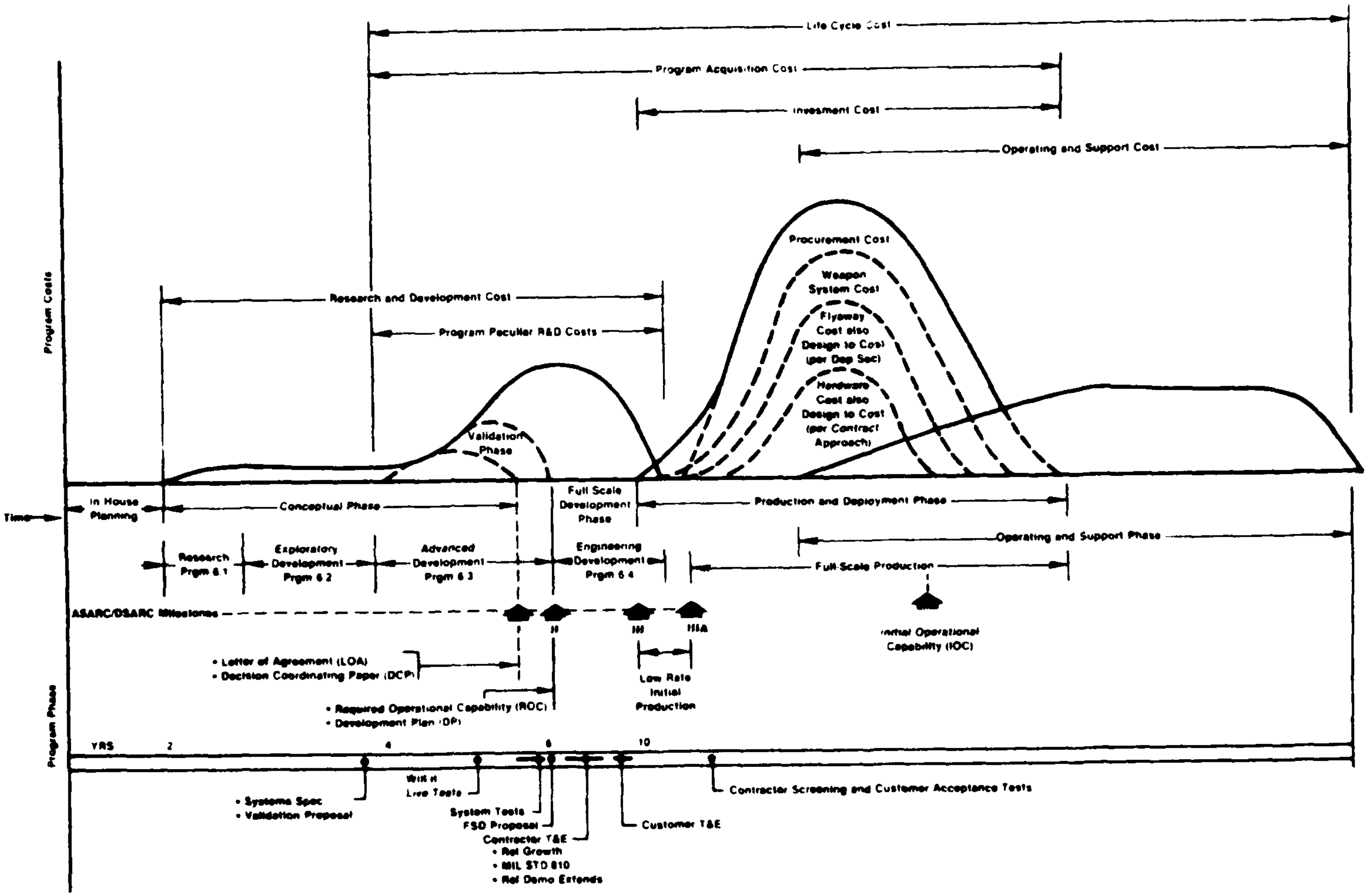

Figure 2: Life-Cycle of a Materiel System

Table I: Environmental Engineering Program Objectives

TECHNICAL

- MINIMIZE ADVERSE EFFECTS OF NATURAL AND INDUCED ENVIRONMENTS ON COMPANY PRODUCTS
- MINIMIZE ADVERSE EFFECTS OF INDUCED ENVIRONMENTS ON PRODUCT CREW OR OPERATORS
- MINIMIZE ADVERSE EFFECTS OF COMPANY PRODUCTS (INCL MFGR AND HANDLING) ON SURROUNDING ENVIRONMENTS

ADMINISTRATIVE

- ESTABLISH AND MAINTAIN CORPORATE MEMORY IN ENVIRONMENTS
- SERVE AS POINT OF ACCOUNTABILITY FOR ENVIRONMENTS
- INTEGRATE ENVIRONMENTAL EFFORTS THROUGHOUT RDT&E PROGRAM PHASES

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Table II: Environmental Engineering Program Functions

- Define life-cycle environments and release design and test conditions
- Recommend and review designs for environmental adequacy
- Perform environmental testing
- Verify field environments, assess failures/corrective actions
- Assess environmental impact of product production and operation

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Table III: Environmental Engineering Program Tasks

R (Research)	1 - Prediction, design and testing methods development
	2 - Environmental data bank development
D (Development)	3 - Environmental configuration trade-offs
	4 - Prepare environmental program plan
	5 - Define environments
	6 - Establish design and test requirements
	7 - Design for environments
T (Testing)	8 - Engr (empirical) design tests
	9 - Design evaluation tests
	10 - Reliability growth (TAAF) tests
	11 - Design proof tests
	12 - Reliability demo or qual tests
	13 - Environmental production screening tests
	14 - Production acceptance test and evaluation
E (Evaluation)	15 - Audit manufacturing process (design changes, workmanship, etc)
	16 - Analyze test and operational failures for environmental causes
	17 - Evaluate operational environments/effects
	18 - Evaluate environmental program

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Platform	Candidate Environments	Test Type	Hardware Assembly Level (Example)
Aircraft	Acoustics	Engr Design	Piece Parts
Ground Transportation	Shock and Vibration	Design Evaluation	Subassembly (PC Card)
Stationary	Moisture	TAAF	Modules (Amplifier)
Seacraft	Thermal	Design Proof	Equipment (Seeker)
Space	Thermal Shock	Rel Demonstration	Subsystem (Guidance Section)
Missile	Altitude	Prod. Screening	System (Store)
	EMI	PAT&E	
	Climatics		

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Figure 3: Combined Environments Definition Variables

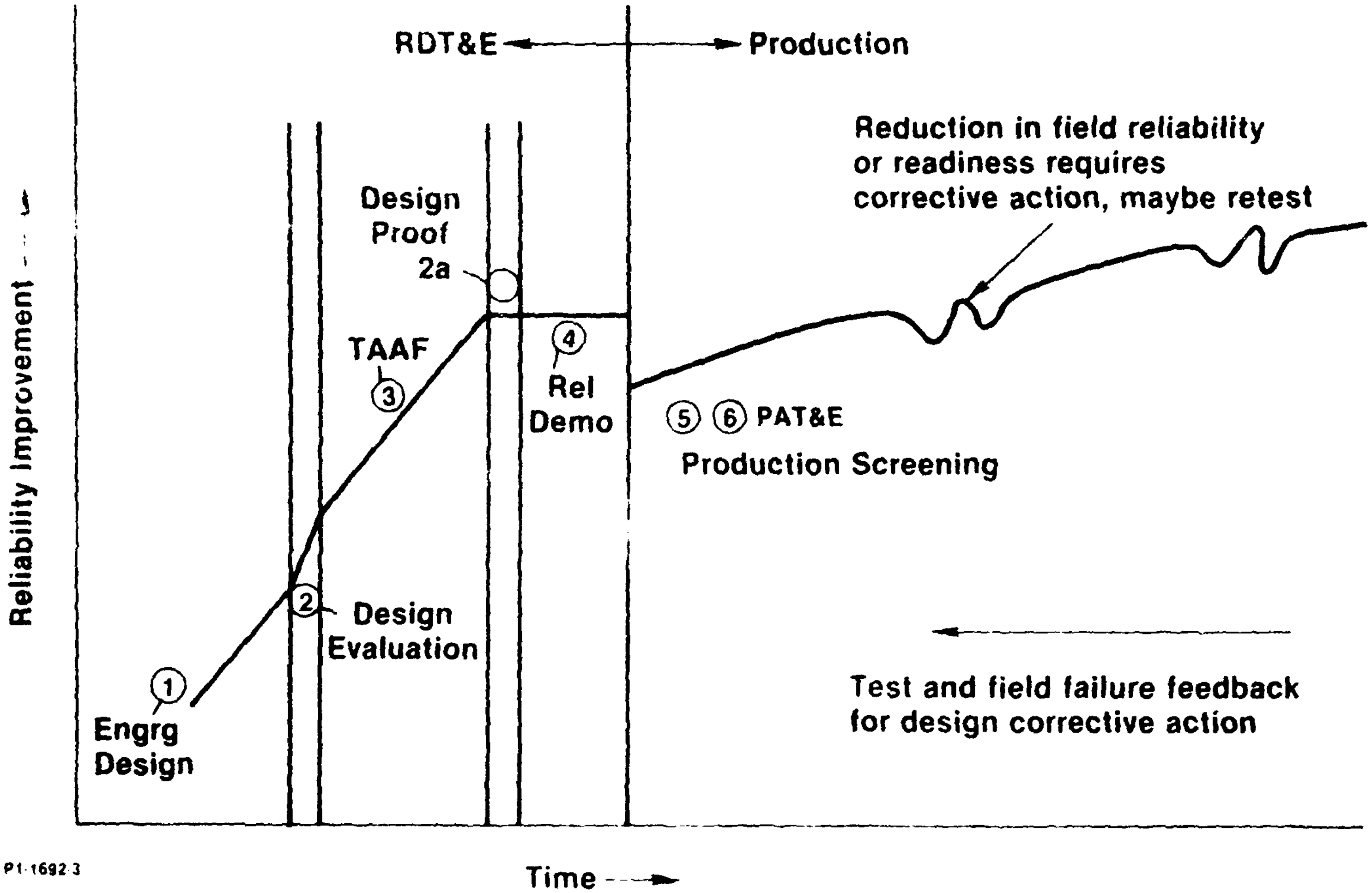

Figure 4: Reliability Improvement Trend with Environmental Testing

Table IV: Summarized Test Characteristics

Ref	No. on Figure 2	1	2	3	2a	4	5	6
1	Title	Engrg Design (Design-Test-Design)	Design-Evaluation	TAAF *Test-Anal-Fix*	Design Proof (Env Qual)	Rel Demo	Production Screening with "Burn-In"	PAT&E
2	*Major Purpose*	Engrg Design (Information - Trade-Off Design *Alternatives* Under Env Exposure	Okays Design for TAAF Entree	Reliability Growth	Contract Gate - Proves Design Okay To Produce	Contract Gate Go-*Ahead to Prod*	Disclose Workmanship Defects, Infant Mortality	Maintain Quality
3	Primary Beneficiary	Producer	Producer	Producer	Consumer	Consumer	Producer	Consumer
4	Length *of* Test(s)	*Many Short (Days)* Test Over Several Weeks	Several Days	Months	Days	Months	Hours	Week(s)
5	*Level of Env*	Any	Service Extremes	Time Varying	Service Extremes	Varying	Constant Sufficient for Purpose	Varying
6	Env Desc	As *Appropriate* (Stimulation)	(Simulation)	Life Cycle Profile (Simulation)	Simulation of Extremes	Life-Cycle Profile (Simulation)	(Stimulation)	Life-Cycle *Profile* (Simulation)
7	*Separate or* Combined Environments	Separate	Combined	Combined	Combined and *Some Separate*	Combined	3 or 4 Combined Environments	3 or 4 Combined
8	Optimum Assy Level Utility	Black Box	*Modules or* Black Box	Modules or Black Box	Black Box or "Set"	Complete Set - e.g Antenna, Receiver Amp, Display and Cables	All	Complete Unit (Sample)
9	Related Standards *and* Specifications	MIL-A-8870	MIL-STD-810	DARCOM P702-4	MIL-STD-810 MIL STD 1670	MIL-STD-781	NAVMAT P 9492 IES - RP	MIL STD 781
10	*Rel Information* Output?	Probably Not	No	Yes	No	Yes	No	No
11	Specimen Consumed	Yes	Yes	Yes	Yes	Yes	No	No
12	*Schedule Fix and* Retest Time	Yes	Yes	Yes	No	No	Yes	No
13	Optimum Contract Phase Utility	V&D	V&D	FSD/V&D	FSD	FSD End	Prod	Prod

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Table V: Testing Program Summary

Product Equipment, Item Sublevels (Example)

(From: MIL-STD280A, "Military Standard Definitions of Item Levels, Item Exchangeability Models and Related Terms," 7 July 1969).

NOTE.

Necessary Conditions prior to These Tests.

1. Vendor Parts Acceptance Tested prior to Incorporation
2. "Burn-In" Tests To Remove Infant Mortality Done prior to Testing

	Engr Design	Rel Dev (TAAF)	Design Proof	Rel Demo	Prod Screen	Field Tests
1. Piece Parts (Resistor)	S/I				S/III	
2. Subassembly (PC Board with Mounted Parts)	S/I		C1/I		C3/III	
3. Assembly (Audio Frequency Amplifier)	S/I	C2/II	C1/I		C3/III	
4. Unit (Electronic Power Supply)	S/I	C2/II	C1/I	C2/II	C3/III	
5. Group (Antenna Group)	S/I	C2/II	C1/I	C2/II	C3/III	
6. Set (Radar Homing Set with Interconnectors)	S/I	C2/II	C1/I	C2/II	C3/III	
7. Subsystem (Guidance Subsystem)	S/I	C2/II	C1/I	C2/II	C3/III	
8. System (Integrated Missile)			C1/I		C3/III	Actual

Tests:

- S - Separate, Natural and Induced Envir
- C1 - Separate and Combined, S (natural), Then Combined Temp, Vibr and/or Acoustic Humidity/Alt Shock, Elect.
- C2 - Combined, Temp, Vibr and/or Acoustic Humidity, Alt, Shock, Elect.
- C3 - Combined, Temp, Vibr and/or Acoustic, Humidity, Shock, Elect., Natural, as Required

Types: (Time/Level)

- I - (Short, Extremes plus Safety Margins)
- II - (Extended, Operational Levels Statistically Profiled with Time)
- III - (Short Fixed Level Designed To Remove Workmanship Defects)

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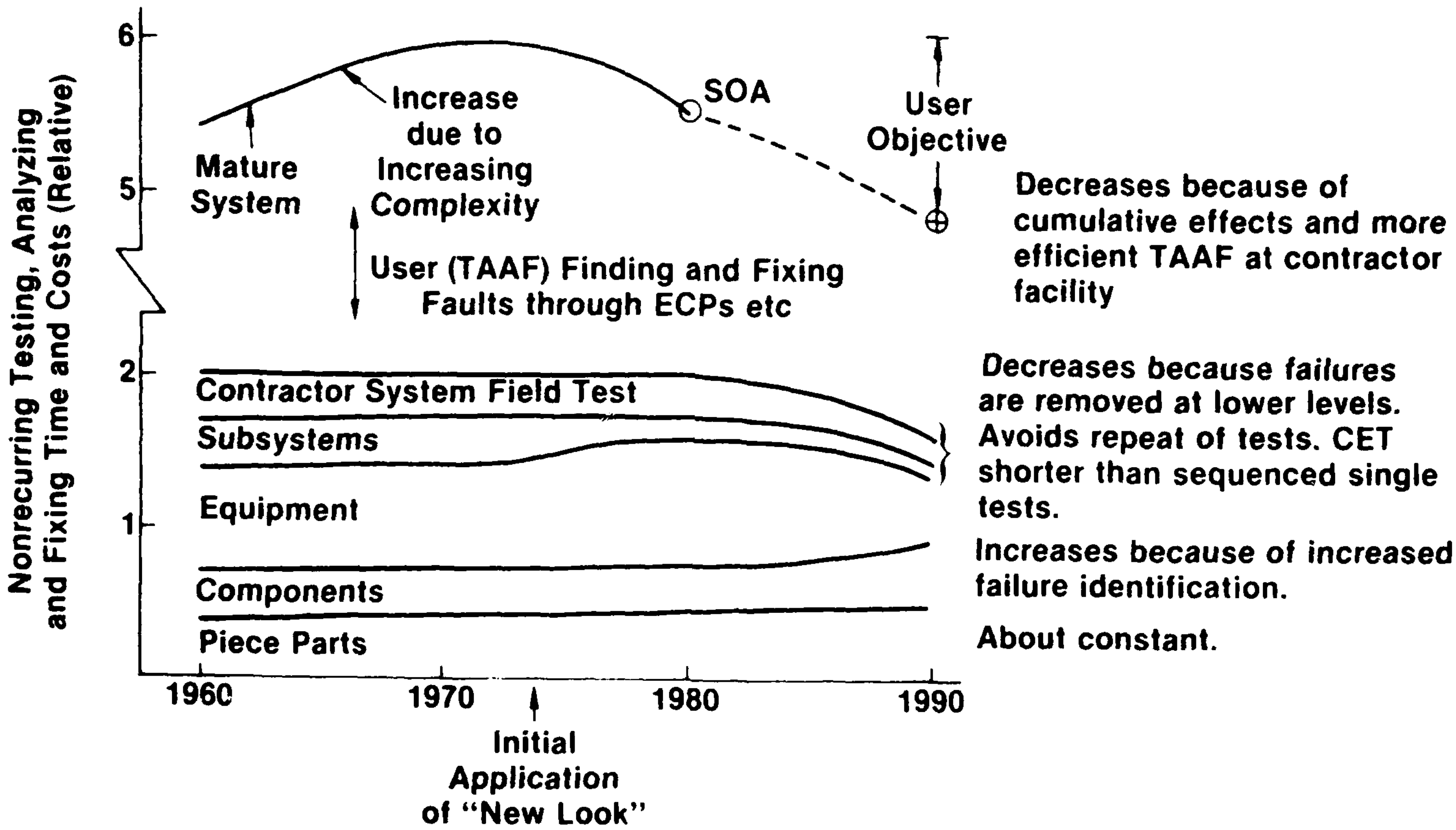

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Figure 5: TAAF Impact on Maturity

CERT EVALUATION PROGRAM - WHAT WAS LEARNED

by

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BACKGROUND

Avionics equipment reliability has been the subject of many broad investigations within the Department of Defense (Refs. 1,2,3,4). In general, the level of deployed system reliability has been less than anticipated by the acquisition agency, desired by the logistician and operational user. Additionally, a significant measure of this disparity has been attributed to the lack of correlation between the laboratory and field environmental stress conditions. One study showed that, on the average, over 50 percent of all field failures of avionics subsystems were due to the effects of temperature, humidity, altitude and vibration (Ref. 5) (Figure 1). However, for any given subsystem, the percentages of failures caused by each environmental stress can strongly diverge from this average value. For example, humidity has been shown to have caused 60 percent of the field failures of one avionics subsystem (Ref. 6), while the direct effects of altitude have caused up to ten percent of the field failures of another subsystem (Ref. 5).

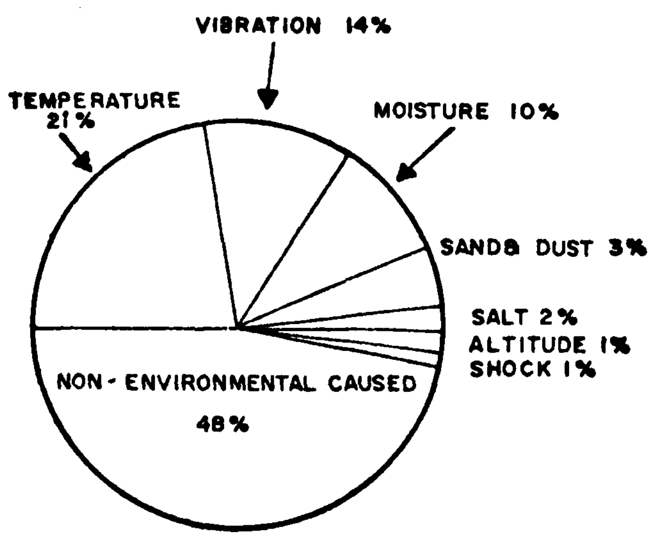


Figure 1. Typical Distribution of Field Failures

BASIS FOR COMBINED ENVIRONMENT RELIABILITY TEST (CERT)

Analysis of environmental data shows that environmental conditions of temperature, humidity, altitude, and vibration vary significantly throughout the mission of an aircraft. In fact, strong correlation exists between the mission of an aircraft and the environmental stress combinations that are impressed upon its avionics at any given instant of time throughout its flight (Ref. 5). (An aircraft performing a combat mission imposes significantly different environmental stresses upon its avionics than if it had been performing a cross-country ferry mission). This correlation between the aircraft flight conditions and the environment under which its avionics must function, suggests that the environmental combinations should be time-sequenced in the test criteria similar to how the aircraft is flown so that the resultant laboratory test conditions would be more representative of the field environment. This concept has been called combined environment mission profile testing. This concept forms the basis for the CERT (combined environment reliability testing) approach evaluated in this study.

COMBINED ENVIRONMENT MISSION PROFILE

Combinations of environmental conditions characteristic of those that occur during aircraft ground park, takeoff, cruise, combat, and other major aircraft flight conditions are put together into a dynamic test sequence that follows the order in which they would occur during typical aircraft missions. Thus, the behavior of the equipment in the laboratory test should closely approach its field performance.

INITIAL TESTS

Mr. Prather and Mr. Earls (Ref. 7) evaluated a combined environments mission test profile that included all reasonable environmental conditions for the test item, a fighter aircraft radar system. The missions and their mix for the aircraft that carried this equipment was generalized in terms of percent of aircraft life spent in each major mission phase (ground park, takoff, climb,

cruise, combat, etc.). The test profile was formulated to maintain a comparable percent of mission phase similarity to the generalized mission. It was found for this aircraft that this similarity could be achieved by using two design missions, a training and a functional checkout mission. The test profile consisted of alternating between the training and the functional checkout missions with a climatic environmental soak between each mission. The climatic soak conditions alternated between tropic and arctic and changed after every second mission.

Upon using this profile, Mr. Prather and Mr. Earls found close agreement between the laboratory and field reported MTBF (mean time between failures). The agreement occurred when the definition of what constituted a failure was made consistent with field practices.

The initial test of the CERT concept created enough interest to plan and conduct a large-scale comprehensive program to evaluate the CERT methodology. The program was jointly accomplished with Aeronautical Systems Division's PRAM Program Office, the ASD Deputy of Engineering, and the Air Force Wright Aeronautical Laboratories (AFWAL).

OVERALL APPROACH

The basic objective of the CERT Evaluation Program was to determine the most cost effective formulation of CERT testing for the early identification of deficiencies and for providing insight into how the equipment will perform in operational service. In order to achieve this objective, a comparison was made of CERT results versus MIL-STD-781 for identifying significant environmentally-induced field failure modes in the laboratory.

The degree of correlation between CERT failure rates and field failure rates was also determined. This was accomplished by selecting test samples broadly representative of the avionics population in regular use in operational aircraft. These test samples, either multiple or single Line Replaceable Unit (LRU) systems, were subjected to mission profile combined environments

representative of their location in the aircraft. They were operated as in actual service and monitored for performance and operating characteristics throughout the test insofar as practical. Out of specification performance was noted, as well as component failures. A detailed failure analysis was conducted on some but not all failed components in an attempt to identify the cause of failure.

The work effort also included determination of facility capabilities and most cost effective facility alternatives, along with recommended appropriate changes in reliability test methods.

SELECTION OF TEST SPECIMEN CANDIDATES

Selection of avionics equipment for CERT evaluation included a broad range of considerations. It was found necessary to categorize types of aircraft, classes of avionics, determine number of subsystems to be tested, and additional detailed selection criteria to prioritize the effort according to rational methodology.

Categories of aircraft include fighter, bomber, cargo and trainer. These aircraft usually have different avionics subsystems, are used in a significantly different manner, thereby having significantly different mission profiles and consequently different environmental conditions.

Categories of avionics investigated include communications/navigations/identification, control and displays, intertial navigation, flight instruments, Electronic Counter-Measure (ECM), electronic flight controls, radars, computers and electro-optical subsystems. Selecting equipment from this broad base was expected to yield results that would effectively evaluate the CERT concept for a wide variety of avionic applications.

Additional selection criteria that were very pertinent to determining equipment to be tested included availability of MIL-STD-781 test data, as this requirement was necessary for a baseline comparison of the degree of effec-

tiveness of new test procedures compared to present or past test methods. Low field MTBF equipment is one criterion which was utilized to provide a failure data base in a cost effective test time. Extensive recent field experience and recent vintage equipment was also desirable. The field experience provides extensive failure data under operational usage for correlation comparison of new laboratory test induced failures. Recent vintage equipment help to insure that test results were applicable to state-of-the-art designs and increased the confidence in obtaining similar results for new equipment. Additional test selection criteria, established to meet program schedule restraints and objectives included availability of spares and replacement units, Aerospace Ground Equipment (AGE) or mockup availability supplemental conditioning (cooling) parameters, size of equipment tested and test chamber availability.

QUANTITY OF SUBSYSTEMS TESTED

Combinations of aircraft performance and type of equipment cooling were considered in determining the number of subsystems to be tested. Aircraft were categorized as high performance and low performance, with either supplemental air (environmental control system [ECS] cooling air) or ambient air. It was decided to concentrate on high performance aircraft since these applictions have the most significant differences in environmental stresses.

For purposes of the evaluation program, it was determined that a minimum of two specimens of each subsystem would be tested. This is based on the assumption that the MTBFs of fielded systems followed a gaussian distribution; and that if the MTBF of a selected subsystem was within one standard deviation of the mean of all fielded subsystem's MTBFs, it was representative of fielded subsystems. Testing two subsystems then ensured (with 90 percent confidence) that a subsystem representative of the field population was being tested.

DURATION OF EACH TEST

A test length of 15 times the equipment field MTBF or three calendar months was established to obtain engineering confidence and to reflect what amount and duration of testing would generally be acceptable in an acquisition program.

NUMBER OF TESTS

Each equipment system was exposed to up to three different test sequences. These test sequences were called CERT, CERT Without Altitude and MIL-STD-781C Appendix B; and were labeled CERT I, II and III, respectively.

TEST DATA GENERATED

A total of six different equipment types were used in the CERT Evaluation Program. These equipment tests are documented in References 8 through 13. Typically, for each test sequence randomly selected, test items were obtained from depot repair lines. Generally, different serial numbered units were used in each test sequence. The test items were bench checked before start of the respective test sequence. During environmental testing, each test item was electrically active and, in most cases, actually operating and performing its function as opposed to just running bit tests or being operated periodically during the test cycle.

Table I lists the equipment tested in the program, the aircraft application simulated, total number of equipment on-hours under environmental test, and number of different serial numbered units used in each test sequence.

Table II summarizes the number of failures that occurred during environmental simulation for each test sequence. The failures that occurred were classified as: cannot duplicate (CND), hard, or adjustment. A CND failure is when the equipment is taken out of the test and checked out in the normal bench environment and no failure could be found. However, the failure generally could be repeated at will by applying the appropriate environmental stress conditions in the test profile. Hard failures are failures which are still present when

the equipment is removed from the test and checked out in the normal bench environment. Typically, a part had to be replaced to correct these failures. Adjustment type failures were categorized as occurring when the performance of the item degraded below the failure threshold; however, it could be returned to required performance levels by adjusting the unit appropriately.

TABLE I. SUMMARY OF CERT EVALUATION PROGRAM

EQUIPMENT	A/C APPL	CERT I TOTAL ON HRS	CERT I # OF CYS USED	CERT II TOTAL ON HRS	CERT II # OF CYS USED	CERT III TOTAL ON HRS	CERT III # OF CYS USED
AN/ARC-164	A-7D	1913	3	-	-	-	-
RT-868A/APX-76	F-15	2082	6	-	-	851	6
CN-1260/ASN-90	A-7D	705	3	-	-	675	3
AN/ARC-109	F-111F	1880	6	1135	5	1392	5
RT-1063B/APX-101	F-15	1008	3	1009	3	930	4
AN/ARN-84	F-5	1122	5	1099	5	1122	5

CERT I: All environments of the mission profile are developed from either actual field data or by use of computerized models based on expected aircraft parameters. The environments include altitude, temperature, rate of change of temperature, humidity, vibration and input voltage.

CERT II: The same as CERT I except that altitude is omitted.

CERT III: The same as CERT II except that the environmental profiles are in a accordance dance with the standardized profiles of MIL-STD-781C. Appendix B, Section 50.4 entitled Combined Environments for Jet Aircraft Equipment.

TABLE II. TEST FAILURES BY CATEGORY

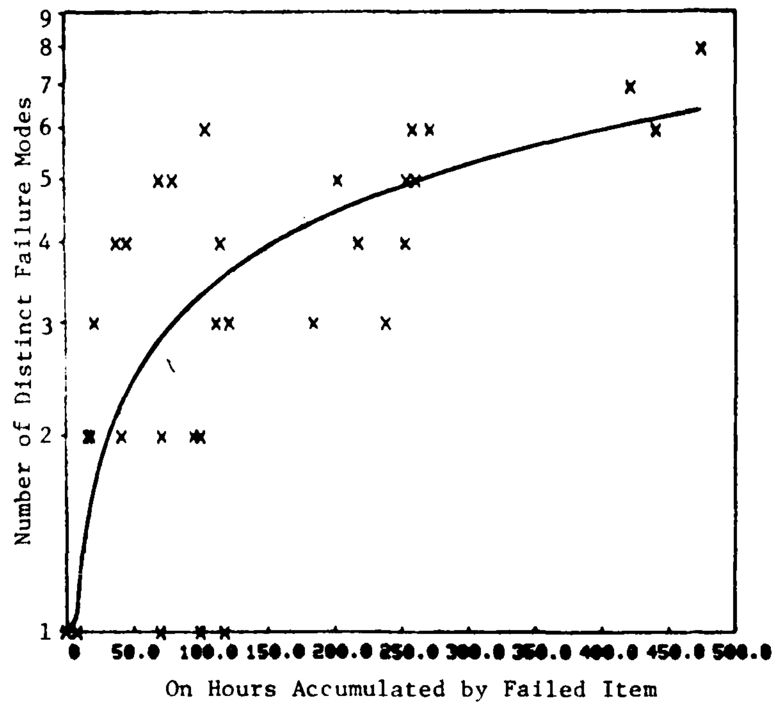
EQUIPMENT	A/C APPL	CERT II			CERT III			CERT III		
		HARD	CND	ADJ	HARD	CND	ADJ	HARD	CND	ADJ
AN/ARC-164	A-7D	13	5	9	-	-	-	-	-	-
RT-868A/APX-76	F-15	18	1	2	-	-	-	9	4	1
CN-1260/ASN-90	A-7D	0	7	0	-	-	-	-	2	-
AN/ARC-109	F-111F	9	9	4	3	3	5	1	2	1
RT-1063B/APX-101	F-15	2	2	0	4	1	-	14	8	0
AN/ARN-84	F-5	7	5	0	6	2	1	6	10	0

ANALYSIS OF TEST DATA AND DISCUSSION

The test data from the CERT Evaluation Program were analyzed to determine the most cost effective formulation of CERT for the early identification of deficiencies and for providing insight into how an equipment item will perform in operational service.

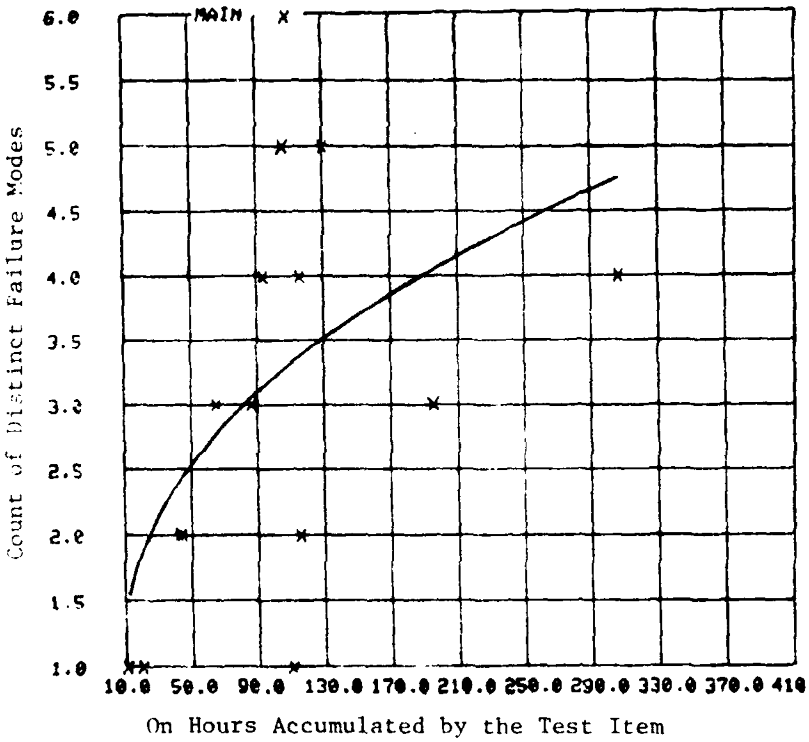
Figure 2 shows that the majority of the modes of failure occurred after a few hundred hours of testing. The curve shown in this figure was a spline fit of the curve $Y=AX^B$. Assuming that the occurrence of a new failure mode follows normal distribution, then 90 percent of the failure modes occurred within 13, 197 or 365 on hours for CERT I, II and III, respectively.

An important consideration was the percentage of the test failure modes that occurred in CERT that were field failure modes. The fewer test peculiar failure modes, the higher the level of engineering confidence that a test identified deficiency also would occur in the field. All CERT failure modes did in fact occur in the field. There were no test peculiar failure modes.

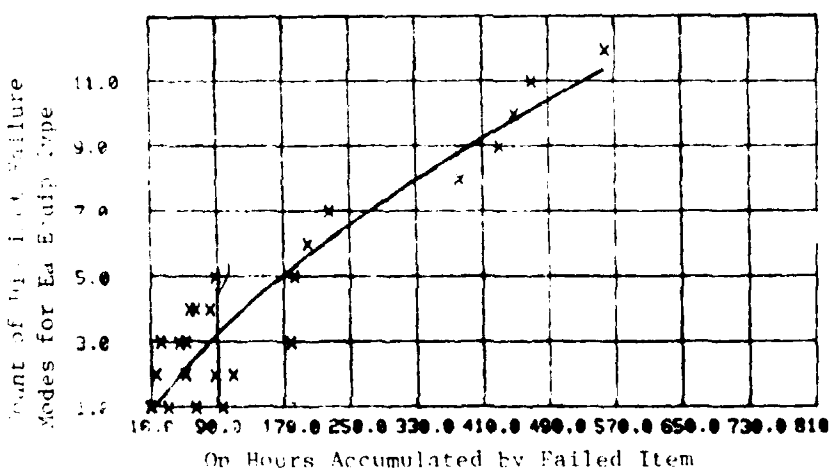


(a) CERT I

Figure 2. Occurrence of Distinct Failure Modes



(b) CERT II



(c) CERT III

Figure 2. Occurrence of Distinct Failure Modes - (Continued)

The significance of this result was somewhat mute because sooner or later everything will fail in the field. A more meaningful way to address this issue was to determine if the test-identified failure modes occur in significant quantities in the field. These modes of failure occur in such large quantities that they may drive logistic costs.

In general, Air Force field data D056 do not indicate the actual repair to the part level so that a direct comparison on failure modes was not possible (Ref. 14). Therefore, it was decided to use an Air Force field maintenance coding system. This code is called "How Malfunctioned" (How Mal), codes which describe why the maintenance was necessary. It is recognized that these codes were somewhat subjective since they depend upon the judgement of the persons recording the failure. A comparison between test and field data was accomplished and the results are shown in Table III.

TABLE III. AVERAGE PERCENT OF FIELD FAILURE HOW MAL CODES OBSERVED IN TEST

CERT	MEAN	STANDARD DEVIATION
I	45.6	28.7
II	31.5	36.8
III	39.4	38.4

From Table III, it appears that CERT I is better, but there was no statistical reason to say that the three CERTs are not equally effective. To put these percentages into perspective, consider the data shown in Figure 1. This figure indicates that about 54 percent of field failures on the average are due to factors or environmental stresses not present in the CERT tests. Therefore, it seems reasonable that, on the average, the best that can be expected from a CERT is that it shows 46 percent of the field failure modes, or field How Mal codes. Therefore, CERT I would be identified as (45.7/46) percent of anticipated quantity of How Malfunction codes. On this basis, the three CERT tests (I, II and III) were, respectively, 99, 68 and 86 percent effective in identifying the anticipated quantity of field How Malfunction codes.

MTBF

Another way of comparing test effectiveness was to compare test MTBF to field MTBF. The limitation of using normal Air Force D056 system data (Ref. 15) was well recognized. Even so, there was no attempt to screen or adjust these data to compensate for the fact that many sources such as personnel errors were not included in the CERT. This approach was selected because the reported field MTBF was the most widely used means of evaluating how an equipment performs in operational service.

Table IV lists the field MTBF values for these equipment items for a 12-month time period that included the period of time that the equipment was used in the CERT Evaluation Program. This helped to increase the likelihood of a consistent configuration for the item used in the program and deployed.

Field data systems would only count two of the three failure categories shown in Table II as being field failures. These two categories are Hard and Adjustment (Ref. 16) since CND laboratory failures are not counted as failures, but as maintenance actions. Using the data shown in Tables I and II, the MTBF values in Table IV were calculated. Table IV also includes initial MIL-STD-781B test values for these equipment items.

TABLE IV. MTBF VALUES

EQUIPMENT	A/C APP	MTBF (HRS)				
		FIELD	CERT I	CERT II	CERT III	MIL-STD-781B
AN/ARC-164	A-7D	44	87	-	-	1000
RT868A/APX-76	F-15	133	104	-	85	1748
CN-1260/ASN-90	A-7D	156	*	-	*	1885
AN/ARC-109	F-111F	95	145	142	969	619
RT-1063B/APX-101	F-15	225	504	252	66	762
AN/ARN-84	F-5	170	160	157	187	670

To interpret and identify data trends, the data were normalized by determining test-to-field MTBF ratios, and calculating confidence intervals using small sample size statistics, Student t distribution. For this calculation, it will be assumed that the MTBF ratios came from a population that is log normally distributed (Ref. 17). For variables that can only be positive, MTBF ratios, the log normal distribution gives a more logical fit since it matches the physical realities that MTBF ratio cannot be negative. The normal distribution extends from minus to plus infinity, while log normal extends from zero to plus infinity. Additionally, a Chi Square goodness of fit test shows that the log normal distribution is a good fit to these data. Figure 3 and Table V show the results of these calculations.

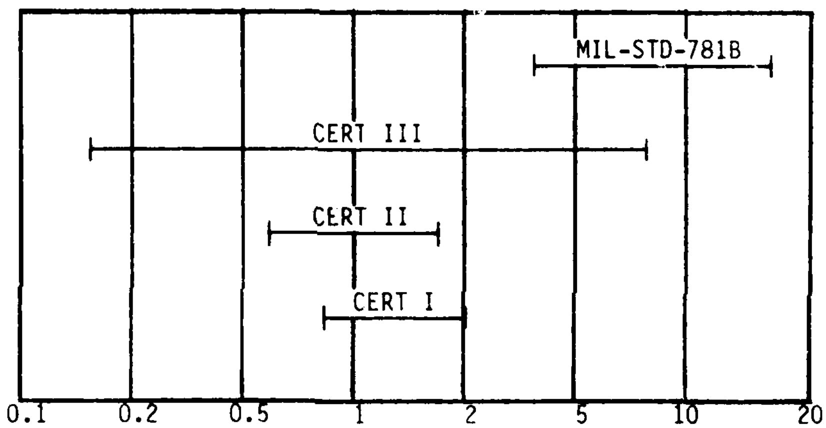


Figure 3. 90% Confidence Intervals for MTBF Ratio

TABLE V. 90% CONFIDENCE BANDS ON TEST-TO-FIELD MTBF RATIOS

	LOWER	UPPER
CERT I	0.94	2.2
CERT II	0.70	1.9
CERT III	0.17	7.1
MIL-STD-781B	4.20	16.4

This analysis showed that there was not a single fixed proportionality constant between test and field MTBF values. This appears reasonable since field data include a significant level of failures caused by factors not included in the CERT. Also, the CERT mission profiles represented nominal or average flight conditions flown by pilots.

An analysis of these test results on a purely statistical basis suggests that there is no difference among the three tests. It is felt by the author that a quotation from Mr. Aaron Levenstein is appropriate:

> "Statistics are like a bikini. What they reveal is suggestive,
> But what they conceal is vital".

In this case, what is concealed is the fact that CERT I and CERT II gave more consistent correlation between test and field results. Factors which tend to muddle a purely statistical analysis of this data are also present in any equipment acquisition program. These factors are: small number of test items, short test duration, and high level of failures induced by factors other than environmental stresses. In any field data, therefore, reliability data should be considered as engineering information.

NEED FOR CERT DURING ACQUISITION PROCESS

CERT has several distinct advantages that should be capitalized during the acquisition process. Because of the realistic nature and combinations of environmental stresses used in the test, an equipment design can be quickly evaluated without any engineering prejudgement as to what environmental stresses, combinations of stresses, or sequences of stresses are the most severe for the specific item to be tested. Therefore, the test item indicates where its defects and deficiencies are and what stress states are most critical very [illegible] without a lot of engineering prejudgement.

During the cost effectiveness study (Ref. 14), Hughes Aircraft Company identified seven failure modes that were never observed with any traditional testing accomplished on the equipment listed in Table I. The occurrence of these field failure modes during CERT may have been due to environmental stress synergism, or stress sequence. In either event, these seven field failure modes were significant field failure modes for these systems.

DURATION OF TESTING

The length of the tests in the CERT Evaluation Program was relatively short when compared to traditional reliability demonstration tests and longer than most environmental qualification tests. The duration of any testing effort is somewhat related to reliability requirements. Traditionally, because of the overly optimistic reliability predictions that are given during the acquisition of a system, the equipment user asked for much more reliability than he needed. For example, look at Figure 3; MIL-STD-781B test MTBF values are about eight times greater than what was achieved in deployment. Therefore, an equipment user will request more reliability than actually needed so that the delivered equipment reliability may meet his real requirements. This over-requesting of reliability requirements drives test costs because test durations have been traditionally based on requested reliability in order to achieve statistical confidence in the demonstrated MTBF values.

Instead of attempting to fix the test duration on the basis of statistical confidence on MTBF values, a different approach seems to be appropriate based on data presented herein. Consider Figure 2, which shows that 300 to 400 operating hours under test identifies the majority to field failure modes to be observed in the test. Any additional testing beyond this point tends to just repeat the already observed failure modes. A study by Hughes found that between 300 to 600 operating hours per test item are needed to identify failure modes that would not appear in any traditional test (Ref. 14). A total of 1300 operating hours among four test items would be needed to have high confidence that a unique mode of failure, if possible, could occur.

COST EFFECTIVENESS

The cost effectiveness of doing CERT was studied by Hughes Aircraft (Ref. 14). The study approach was to quantify the cost effectiveness. To accomplish this study, Hughes reviewed all the data collected on the six equipments shown in Table I. The failures that occurred in the CERT program were screened to determine which failures could be considered as being "correctable" failures. To be classified as correctable, the failure had to meet the following criteria:

a. Can reasonably be caused by the field environment.
b. Can be expected to occur in all or at least a significant proportion of the serial numbers of the equipment.
c. Could have been eliminated from future occurrence by a design change which was technologically possible at the time of the original development of the equipment.
d. Would have required the use of mission profile testing to be detected; i.e., would not be revealed by more traditional test program.

Because of the restrictive nature of these criteria, only 7 failure modes were considered in the costing analysis. These criteria were appropriate for a quantified cost study but, as recognized by Hughes, the cost savings benefits estimated by this approach will be significantly understated.

The cost effectiveness analysis consisted of determining the cost of conducting CERT, making design changes, and implementing these design changes in the production line. These costs were compared to the logistic maintenance labor and spare part savings to be accrued if these correctable failures did not occur in the field. It was found that for these six equipments, these costs were recovered within two years through logistic maintenance cost savings.

The equipment used in the CERT Evaluation Program were systems that were generally more mature than a new product just being produced. A less mature system will have more defects and deficiencies that will tend to make CERT appear even more cost effective.

Another major cost effectiveness consideration of CERT is suggested by Figure 3. The amount of test time needed to test an equipment can be reduced if the equipment user and acquisition agency make use of the lower ratios between test and field MTBF that exist for CERT. Instead of asking for a 1000 hour MTBF when only 100 is desired, significant cost savings may be realized in the design process, use of appropriate parts quality, and test durations.

CONCLUSIONS

Two sets of conclusions are presented because of a difference in viewpoint as to how to interpret the data. Both viewpoints are presented because it is felt that each perspective is useful to understand the CERT program results.

The nine following conclusions were reached by Hughes Aircraft in their CERT evaluation program:

1. The additional costs associated with CERT I, i. e., with altitude, are not justified.
2. The cost-benefits of CERT testing during development/early production will probably exceed the values determined in this study due to: a) a large number of correctable failures can be expected; b) any RTOK's uncovered and corrected will increase the potential field savings.
3. On the average, at least one correctable failure will be found in a properly conducted Mission Profile Test. This will pay for itself in between 2 and 4 years, given that a substantial inventory is planned.
4. The above third conclusion is unlikely to be valid unless a minimum of four test samples are employed for at least 1300 total hours of test, with approximately equal hours on each sample.

5. The potential cost benefits of CERT testing can be very easily dissipated by a number of factors extraneous to the technical merits of the test. Most importantly, over-zealous corrective action on isolated failures which are not field-related and truly correctable will rapidly negate the potential benefits.
6. The prior conclusions should not be taken to infer that CERT testing will significantly improved field reliability. The proportion of the total field failures (or CERT test incidents) which were correctable was generally small. Thus only a small increase in field reliability should be expected.
7. The ability of Mission Profile Testing to replicate field failure rates and modes is marginal on mature equipment. The results from testing development/early production equipment will probably be even less representative of what can be expected to occur in field use. On the other hand, it is undoubtedly the best available test technique, providing its lack of precision is recognized.
8. In order to assess the potential cost benefit of Mission Profile Testing, it was necessary to consider not only when such testing is appropriate but also when it would be inappropriate and, therefore uneconomic. Based on the analyses of failure data and failure rates described herein, and given the basic premise that economical screening must be a highly accelerated test, it is concluded that Mission Profile Test conditions are totally inappropriate as the conditions for environmental stress screening.

9. If a single conclusion from this study can be attempted, it is that judicious use of Mission Profile Testing will, on average, be beneficial - but it is not a panacea.

The following conclusions were reached by the author in the CERT Evaluation Program:

1. CERT has been found to be cost effective. On the average, payback of the costs associated with conduct of CERT is returned in less than two years of field deployment because of reduced maintenance costs.
2. CERT should be used either in late development and/or early production when there is a mature, somewhat stable design. A minimum of four test items, each of which is exposed to a minimum of 300 operating on hours under environmental stress, is recommended.
3. There are no significant differences between CERT I, II and III for the identification of failure modes. Thus, the inclusion of altitude in the test is not justified.
4. The more realistic the environmental stress conditions used in CERT, the more consistent are the test-to-field MTBF ratios. Specifically, the 90 percent confidence branch on test-to-field MTBF ratios were 0.94 to 2.2, 0.7 to 1.9 and 0.17 to 7.1 for CERT I, II and III, respectively.
5. CERT identified failure modes that occur in the field but were never observed in any traditional single environment or reliability test.
6. Reliability requirements need to be more realistically stated so that the user who wants a 50 hour MTBF does not ask for 500 hours. Such over-specification can be eliminated because of the more realistic nature of CERT test MTBF estimates. Significant cost benefits in addition to those identified by Hughes, can be possible from proper statement of reliability requirements.

RECOMMENDATIONS

1. CERT should be used late in equipment development and/or early in production.
2. Reliability requirements need to be stated realistically by the equipment user. The ten to one test-to-field inconsistency of previous reliability demonstration testing no longer exists.
3. CERT Mission Profile Testing should be used for failure mode identification testing as well as tests for estimating field failure rates.
4. CERT testing allows for the use of fewer test items in an integrated testing program. This is achieved because the test conditions are

realistic and do not use up the test item like traditional testing approaches. Thus, a system can be used interchangeably in flight, performance and CERT tests. A short CERT test before flight or performance testing could shake out design bugs that would have delayed these other tests. CERT identifies these problems for corrective action while collecting reliability data.

5. CERT testing could be used in place of several of the traditional testing methods. This is recommended because CERT identifies failure modes that occur in traditional testing in addition to field failure modes not observed in any traditional testing. This approach of integrated testing appears to have additional cost benefits not included in the Hughes cost effectiveness study. These cost savings come from a net reduction in the number of tests to be conducted during equipment acquisition.

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MANAGEMENT LESSONS FROM CERT
OF
AIR-LAUNCHED MISSILES

by

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INTRODUCTION

The Pacific Missile Test Center (PACMISTESTCEN) has been conducting acceptance testing since 1959 of guided missiles produced for the Navy. Initially, the acceptance programs were proof firing programs in which a monthly sample of missiles were fired to assess production quality. In the early 1970's, the increasing costs of missiles and the costs of firing forced the Navy to investigate non-destructive test techniques to replace the proof firing programs. Following considerable research into test techniques, a form of Combined Environmental Reliability Testing (CERT) was developed. A test was designed for each missile system that consisted of subjecting the missile to combined environmental conditions closely simulating the operating environments. As these tests were developed, they were used for different purposes. The major applications are summarized in Table I. The missile types to which the test were applied are shown in Table II.

In the following discussion the author will try to pass on some of the lessons learned at PACMISTESTCEN. This paper will concentrate on the management aspects of CERT; technical issues have been addressed elsewhere (Refs. 1 - 7). Also, some unsolved problems that have arisen in CERT of missiles will be mentioned.

TABLE 1. TYPICAL APPLICATIONS

TEST TYPE	PURPOSE	APPLICATION	TYPE OF INFORMATION REQUIRED: FAILURE MODES	TIME-TO-FAILURE
Test, Analyze, and Fix (TAAF)	Reveal and correct design weaknesses	Development of a more reliable design prior to production.	Essential to induce potential service failures.	Not important.
Reliability Demonstration	Show whether or not a design meets the specified reliability.	Start of production is usually based on a successful reliability demonstration.	Important only if the demonstration is unsuccessful.	Essential.
Debugging or Screening	Reveal workmanship or component defects before a production unit leaves the factory, i.e., while repair is cheap.	Part of the manufacturer's internal testing to assure delivery of reliable units during production	Essential to induce failures in defective areas; such failures should <u>not</u> then appear in service.	Not important.
Lot Acceptance	Estimate the MTBF of the lot units from the time-to-failure of a small sample.	Determination as to whether the lot is of acceptable quality.	Important only if the lot is rejected.	Essential that successive lot measures be consistent and comparable. Baseline similarity to service MTBF is desirable.
Source Comparison	Determine the relative reliability of units from the time-to-failure of a small sample.	Determination as to which of two sources should get the larger share of a production buy.	Important for improvements at the poorer source.	Only consistency and comparability is essential.

TABLE II. MISSILE PROGRAM APPLICATION OF CERT AT PMTS

	AIM-7E	AIM-54A	AIM-7F	AIS Pod	SKYFLASH	HARPOON	SHRIKE	AIM-9G	AIM-9H	AIM-9L	AIM-7M	HARM
Test, Analyze and Fix			X								S	
Reliability Demonstration			X		X					X	X	X
Debugging of Screen				X								
Lot Acceptance or Monitoring (1)	X	X	X			X	X	X	X	X	(2)	(2)
Source Comparison	X		X		X							(2)

(1) These are or were continuing tests conducted on monthly or quarterly samples.

(2) These are planned.

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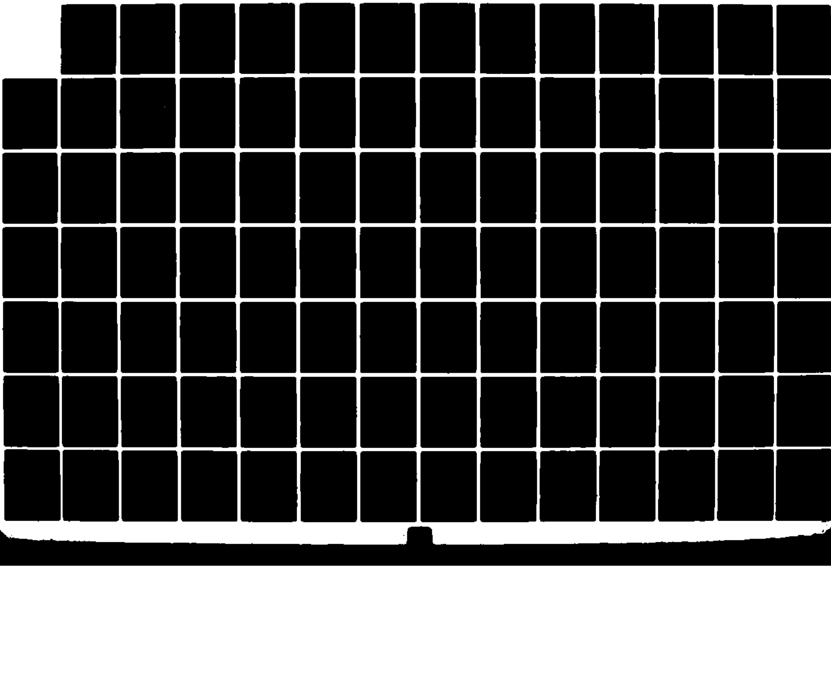

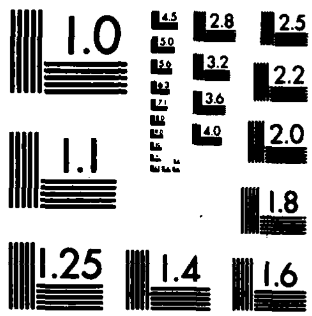
1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

DISCUSSION

There are some lessons which are not peculiar to Combined Environmental Reliability Test (CERT), but which were learned at the Pacific Missile Test Center (PACMISTESTCEN) as a consequence of applying CERT. These lessons would apply to any reliability test, but they became more important simply because CERT was a better test.

First, we became aware that a reliability test is only part of a process. The whole process must include analysis of failures, formulation of corrective action, and a decision as whether the corrective action is to be taken. To conduct a CERT without these elements is like strengthening one link in a chain. The other elements were not so important when standardized reliability tests were run simply because the results were not expected to be realistic anyway. One of the ways of ensuring closure of the failure analysis and correction loop which has worked well at PACMISTESTCEN is the establishment of a Failure Analysis Review Board (FARB). There is one FARB for each missile type; it meets regularly and it consists of representatives from the government and the manufacturer. It is a technical working group which reviews and approves failure analyses and proposed corrective actions. It does not decide on implementation of corrective actions.

Second, another lesson which is more general than CERT, is that there is an optimum level of assembly or aggregation at which to test. If a reliability test is conducted at a low level, say modules within a missile, the Mean-Time-Between-Failure (MTBF) requirement will be high and many different assemblies must be tested. Consequently, the testing will be long and costly. On the other hand, if testing is attempted at a very high level, say a complete avionics suite, the MTBF will be short and the number of functions to be tested/monitored will be great. Consequently, the test set-up will be very costly and it may be impossible to check all functions in a time less than the MTBF. In this case, CERT will lose many of its advantages relative to simply putting the item into service and observing failures. Between these two extremes is a range of MTBFs and functional complexity which, happily for

PACMISTESTCEN, includes air-launched missiles. Functional tests require a few minutes to an hour depending on the thoroughness. Missile MTBFs when PACMISTESTCEN began CERT were generally less than 100 hours, which seemed about right. Now missile MTBFs are in the range of 500 to 1000 hours. Because of this higher MTBF, missiles are now tested four to six at a time so that the aggregate MTBF is still around 100 hours. The increased MTBF combined with the complexity of functional test equipment also led to another lesson.

One of the most important lessons we learned is that a standard or universal chamber design was not possible. Tailoring the test to a specific missile mission profile required a large variety of temperature conditioning equipment, acoustic systems and, from a cost consideration, different volumes of the very important energy source, low pressure air. It became impractical to specify the environmental equipment until a general review of the potential mission profile was completed. Several other factors influenced this decision. Design and fabrication of the necessary instrumentation to energize and monitor the missile was quite often the most expensive and most difficult part of the facility development. The magnitude and complexity of the instrumentation normally did not lend itself to a temporary installation. One other factor related to dedicated chambers was a corresponding increase in missile reliability that has occurred in the past six years. The initial missiles tested had MTBFs between 50 and 100 hours. A reliability test could be completed in a relatively short time now, with missiles having MTBFs in the 500 to 1000 hour range, test durations require chambers to operate around-the-clock most of the time. There is no opportunity for facility sharing.

This around-the-clock operation also taught us something about people. Our first CERT facilities were manually operated. Both the environments and the missile functional tests required a fairly high level of technician training and attention. Inevitably there were errors and lapses. So, we began to automate the tests so that they required only monitoring and a little button pushing every few hours. This has allowed us to use our skilled technicians on more productive dvelopment work; while operation of the CERTs is handled by less skilled operators. But, it has not been an improvement in terms of test control and consistency. With so little required activity, the operators get

bored and fail to do the required monitoring. This has led to some interesting data on missile durability under extreme environments. For example, missiles will operate after being cooled to -90°C, but not after being cooled to -95°C. To avoid obtaining more such information like this, we are now making each CERT chamber fully automated.

The lessons specific to CERT primarily came in trying for the greater realism which a CERT should attain. The fundamental lesson here is that there must be a clear, objective audit trail from measured environments and service mission descriptions to the CERT environments. THe whole usefulness of CERT, as opposed to standardized reliability tests, lies in its faithfulness to service environments. It is this faithfulness that justifies confidence in CERT results even before service results are available. If this faithfulness is sacrificed to some all-purpose standard or some waving of arms and feeling of the gut, the resulting test will be worthless. It will be worthless even if it gives the right results because no one will have confidence that they are right. Naturally, there will be compromises in the faithfulness of the test, compromises necessitated by facility capabilities, funding, schedule, and all the other constraints the test engineer is heir to. The important thing is that these compromises (a) be defensible as engineering judgements, and (b) be documented as part of the audit trail.

The compromises that arise because of facility limitations lead to one of the outstanding problems in CERT: When two environments, desired and achieved, are complex and multidimensional as they are in CERT, how do you objectively quantify their degree of similarity? It is anticipated that this problem will become more and more pressing as more manufacturers build CERT facilities because the question will arise as to which facilities are most closely reproducing the desired environment. This will be followed by the even more troublesome question: How close is close enough? In the area of vibration similitude, we have developed some measures at PACMISTESTCEN and eventually we may be able to say how close is close enough, but much remains to be done.

At the other end of audit trail from the test similitude problem, there is another problem, the fuzzy requirement. Because CERT environments are based on mission profiles, the mission profiles need to be defined. Too often the Decision Coordinating Paper or Specific Operational Requirement does not do

this. Then, during the design process, various environments are specified without reference to any missions. Finally, during development, when a CERT is wanted, the misssions are defined for the first time. It should surprise no one that the environments derived from those missions are often found to conflict with those specified for design. The lesson here is to define missions in the very beginning.

SUMMARY

From a management standpoint, the most important thing to realize about CERT is that it is only one part of a process, or more correctly, of two different processes. First, it is the last step in a process of environmental definition; a process which should begin with mission definition in the Design Concept stage. Second, it is the discovery step in the process of discovering reliability problems and correcting them. Without these processes, CERT is an empty exercise. With them, it is a useful and important tool.

BIOGRAPHY

D. Brent Meeker is head of the Production Acceptance Test and Evaluation Engineering Branch at the Pacific Missile Test Center, Point Mugu, Californa. He is one of a small group of engineers who developed and applied Combined Environmental Reliability Tests for air-launched missiles, beginning in 1972. Except for four years graduate work in physics at the University of Texas, he has worked at Point Mugu since 1962.

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HIDDEN BENEFITS
OF A
COMBINED ENVIRONMENT RELIABILITY TEST (CERT)
IN AN
ACQUISITION PROGRAM

by

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INTRODUCTION

By now most of the avionics community has heard, at least once, about the success of the Combined Environment Reliability Test concept in replicating field failure rates and modes. This paper will not present more on the primary reason that a Combined Environment Reliability Test should be a part of any avionics acquisition program. It will, instead, present for your consideration some other findings of the CERT evaluation program and concurrent reliability demonstration flyoffs that are significant and could contribute to the reliability and maintainability of avionics systems. These findings are important to you because they show that insufficient attention has been given to some important aspects of these systems.

The thrust of this paper can be summed up by paraphrasing the late George Meany. When Mr. Meany was asked the function of a labor union, he replied "to demand more and more here and now." This paper will ask that we attempt to achieve more and more sooner and will show the benefits of so doing.

If you conceive of any weapons system and its subsystems as a group of stools, each doing its share to support the mission, the neglected aspects mentioned previously will be apparent.

The legs of any of these subsystem "stools" would be those of the stool pictured in Figure 1. Obviously the stability of the stool and, therefore, its support of the mission depend on the quality of the legs, that is, the quality of the:

System Hardware

Maintenance Support Hardware

Software - Both System and Maintenance Support

Personnel Performance.

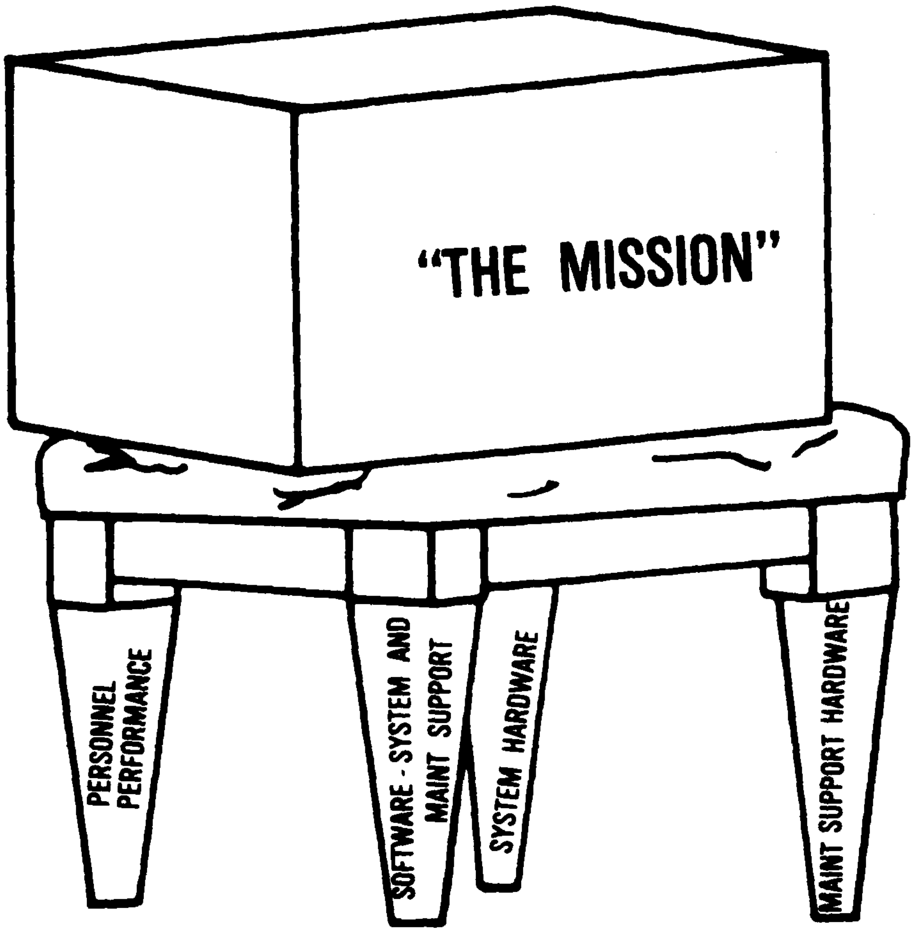


Figure 1. Subsystem Mission Support Concept

The systems tested in the evaluation program and flyoffs had defective hardware and/or software. Undoubtedly, these deficiencies had not only their direct effects on maintenance costs but an indirect one of lowered personnel performance as well.

Specifically, it was found that:

1) In at least one instance, overly difficult system operating procedures were identified by CERT.

2) Repair and maintenance Technical Orders still contained important technical errors and omissions several years after initial deployment of the system.

3) Minimum Performance Test (MPT) limits and procedures that were as much as four years old still contained errors, omissions, and hard to understand sections.

(These findings show that CERT can detect system and maintenance support software flaws.)

4) Non-failure causes of maintenance expense that had already occurred in the field were encountered during CERTs.

5) CNDs occurred during a CERT at a rate similar to that encountered in the field.

(Findings 4 and 5 are two more examples of CERT's ability to detect system hardware malfunctions.)

6) Some test equipment specified for system maintenance was either not available, less suitable, and/or less easy to use than other equipments. More important is the fact that some test sets had significant design and MTBF problems.

(Finding 6 shows that CERT detects maintenance support hardware problems.)

Since CERTs identified these problems on already deployed systems, it seems reasonable that a CERT would reveal the existence of similar types of problems early in an acquisition program.

The hidden benefits of a CERT, then, are that it will reveal, even spotlight:

1) System software problems

2) Defects in the maintenance support software and equipment

3) The existence of volatile system hardware problems (CNDs or RETOKs)

as well as its primary objective:

Nonvolatile system hardware defects.

CERT was conceived for use in an acquisition program as a reliability demonstration or growth test to be conducted singularly or competitively prior to the buy decision. When CERT or a CERT is referred to in this paper, it will be in this same context; that is, a mission profile combination of 4 to 6

environmental parameters used to improve or demonstrate reliability in a long-duration test.

It will also be recommended that the CERT concept be applied to first article qualification and production acceptance testing of parts, modules, and systems. By CERT concept is meant the combination of environmental parameters, either mission profile or reasonable extremes, in a short-to medium-duration test. It will be emphasized that in the area of acceptance testing the CERT concept is particularly valuable as a product improvement check tool. Before expanding on these points and citing occurrences from the evaluation program and flyoffs, some background on the program itself would seem to be in order.

BACKGROUND

The CERT Evaluation Program was conceived by members of the Air Force Flight Dynamics Laboratory (now Air Force Wright Aeronautical Laboratories - Flight Dynamics Laboratory) and the Aeronautical Systems Division Engineering Deputate in 1976. The technical merit and relative cost effectiveness of various combinations of environmental parameters were to be determined by comparing the failure modes and rates achieved in the laboratory to those experienced in the field for each of the systems tested. These systems were current USAF inventory avionics items tested according to mission profiles of various examples of the several categories of USAF aircraft. Figure 2 shows the types of equipment tested and the aircraft from which the mission profiles were derived.

Figure 3 shows the 4 major components of a combined environment test plan and the information sources for these components. Each test was planned by an engineer and an experienced avionics technician whose prime concern was that the operational, maintenance, and environmental conditions were realistic.

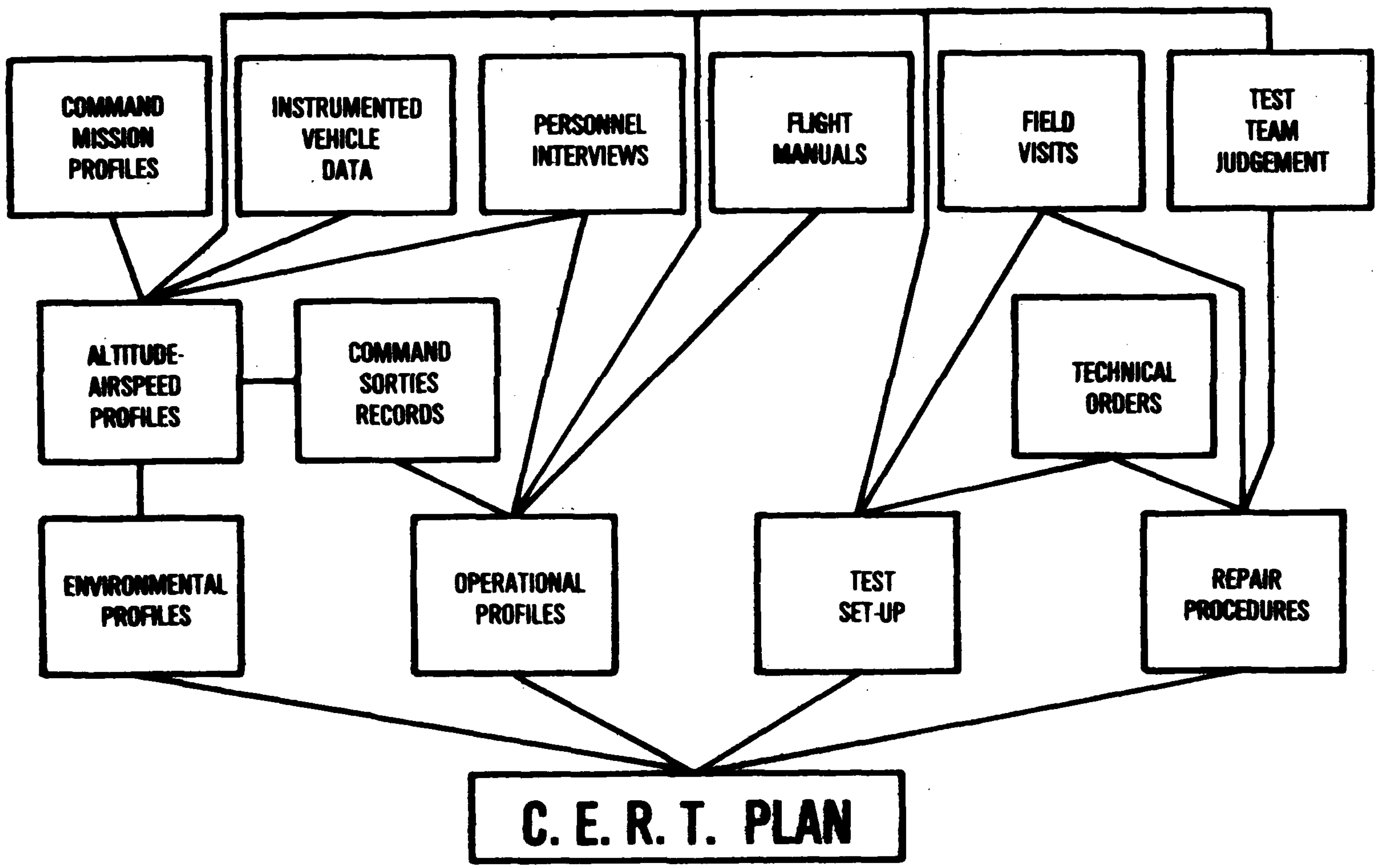
The process of deriving realistic environmental profiles will not be discussed here. Realistic operational conditions were assured by use of the applicable aircraft flight manuals and information gathered from the operational commands, especially interviews with pilots and other operations personnel.

It was the goal of the program to both operate and repair the avionics systems using normal flight line and field shop test sets. The environment to which both the operating and repair test sets were exposed was that of a normal field shop. But the useage rate of the operating sets was considerably accelerated compared to normal. Due to the compression of ground park time, these sets were operated 24 hours per day, 5 or 6 days each week, for approximately two months per test sequence.

CERT EVALUATION PROGRAM

EQUIPMENT TYPES TESTED	MISSION PROFILES FROM
COMMUNICATIONS RADIOS	B52
(2)	F5
	FB111A
IFF's	A10A
(2)	F15 (BOTH EQUIPMENTS)
IMU (1)	A7D
NAVIGATION RADAR (1)	B52
NAVIGATION RADIOS	C130
(2)	F5
	FB111A

Figure 2



COMMAND MISSION PROFILES
INSTRUMENTED VEHICLE DATA
PERSONNEL INTERVIEWS
FLIGHT MANUALS
FIELD VISITS
TEST TEAM JUDGEMENT
ALTITUDE-AIRSPEED PROFILES
COMMAND SORTIES RECORDS
TECHNICAL ORDERS
ENVIRONMENTAL PROFILES
OPERATIONAL PROFILES
TEST SET-UP
REPAIR PROCEDURES
C. E. R. T. PLAN

Figure 3

Each test plan required that steps in the trouble isolation process to an LRU at the chamber, or to an SRU at the CERT repair shop, be completely in accordance with the planners' understanding of flight line and field shop procedures. This understanding was gained from applicable Technical Orders and information gathered from the operating commands, especially interviews with maintenance officers, and flight line and field shop personnel.

Only in the area of SRU logistics was there significant deviation from normal procedures. In order to determine the failed part(s) and have the failure mode confirmed, failed SRUs were shipped directly to the depot, repaired, and returned directly to the CERT facility. The depot also returned the failed parts along with a report on their troubleshooting and repair for use in analysis.

While the CERT Evaluation Program was in progress, two reliability demonstration flyoffs were conducted in the CERT facilities. The flyoffs consisted of operating the competing manufacturers' systems under environmental and operational profiles derived for the aircraft to which the system was to be fitted. The repair procedures during these flyoffs differed from those in the evaluation program in that the manufacturers' technicians performed all maintenance and design changes after a failure was permitted. The information from these CERTs was used to establish relative life-cycle costs for the various manufacturers' systems and identify areas for product improvement.

From the above, it can be seen that a CERT gives a trained team the opportunity to understand, operate, and maintain an avionics system in a human environment that is relatively free of distractions and pressures, yet realistic as to procedures, methods, and equipment operational environment.

With this look at the evaluation program as background, let us now consider the findings of this program in more detail.

EXPANSION AND EXAMPLES

1. Improved Operating Procedures

While simplicity of operation is one of the prime goals of systems designers, this goal is often missed, partly due to their level of expertise and familiarity with the system. A CERT gives an opportunity for evaluation under realistic operational conditions with trained operators and evaluators who have had to learn the system. This learning is guided by the same flight manuals, Technical Orders, and other system software that guide the learning experience of field personnel. The system operation during the CERT is controlled by the same system software and firmware used in field units. An example of CERT's effect can be found in one of the CERT flyoffs of competing systems. One of the systems tested had a long and complex initialization procedure. It is our understanding that the version of this system finally deployed was much easier to initialize.

2. Technical Order Defects

During test planning, the approved Technical Orders are the major source of the following information:

Theory of Operation

Wiring Diagrams for Unit Hook-up

Recommended Troubleshooting and Maintenance Methods.

Approved flight manuals are used to determine when and how the system was used. It was often found that the Technical Orders did not contain sufficient information to allow hook-up and operation of the system. This missing information would have assisted field personnel in troubleshooting and retrofitting. For example, a communications radio was found to employ positive and negative logic in various sections. The T.O. would speak of logic "0" or logic "1" without

giving any clue as to the actual voltage condition. Without this signal level information on lines external to the LRUs, a test setup was not possible. It is felt that the field is forced to look elsewhere for the information, when it is needed, with an attendant loss of time and increased cost.

3. Minimum Performance Test Defects

During test planning the Minimum Performance Test procedures are reviewed to see if they do, indeed, fully check out the system's minimum performance. The MPT limits, built-in test (BIT) limits, as well as knowledge of the operational requirements are used to define a failure. Once the test articles are received the repair technician performs an MPT on each unit and during the progress of the test MPTs are performed on each failed unit. This, in effect, is a proof test of the T.O. and problem areas are quickly identified. For example, during preparation for a test of an IFF transponder the repair technician determined that some parts of the procedure were unclear, others needlessly difficult, and some did not accomplish the desired result. With the concurrence of the test engineer, he rewrote the procedure for his own use. During the course of the test, T.O. changes corrected 50% of all defects and 90% of the very serious ones. It took a little over five months from the time test planning began to completion of the revision; at this point the T.O.s were four years old. A CERT during this acquisition could have resulted in early identification of these deficiencies and four years of reduced maintenance expense.

In this same test, it was found that several failures could have been cleared by an adjustment rather than SRU replacement; this adjustment was authorized at intermediate level but not adequately referenced in the T.O.. How many field shops also failed to make this connection and how much this cost the Air Force cannot easily be determined, but a CERT during the acquisition

program could have avoided these costs. These three examples show that CERT can identify system and maintenance support software problems. Now let us take a look at some hardware problem examples.

4. Identification of "Nonfailure" Causes of Maintenance Expense

Data from several CERTs indicates that environmentally-caused cost drivers that are not usually discovered as system failures or are not counted as system failures under AFM 66-1 were also identified by CERT. Some examples are: vibration-shortened light bulb life, shock mount breakage, P.C. board delamination, corrosion of metal parts and deposition of corrosion on other parts. Field shop Chiefs were queried concerning board delamination and corrosion deposition problems on the LRUs that had exhibited these problems during CERT; they confirmed their existence in the field.

5. Occurrence of RETOKs

During the course of the evaluation program, it was noted that the CERT flight line CND and field shop RETOK occurrence rates seemed to parallel field rates. An attempt to correlate field and CERT CND modes was inconclusive due to the flight line test methods used in the field and at the CERT facility on the systems available for comparison. A recent study was made of CERT as a RETOK reduction tool. During this study seven of the eleven units under test exhibited malfunctions that were not apparent in the normal shop environment. Five of the seven exhibited the malfunction exhibited in the aircraft. All malfunctions appeared within 24 hours of test, the mean time being 5.9 hours.

Two CND problems that occurred during one of the evaluation program tests were tracked to their root causes. They are presented to give the reader an idea of the environmentally-caused problems that are being experienced with avionics equipment.

1. An IFF system repeatedly was out of MPT and BIT self-test frequency tolerances after a 1/2-hour cold soak at about -65°F. It was proved that the L-band source had a positive temperature coefficient of frequency that caused the BIT tolerances to be exceeded at case temperatures below -20°F. Assuming that BIT self-test test limits reflect the band width of the interrogator-responsor, loss of range must occur in Arctic and high-altitude environments.

2. Mission profiles for the APX-101/A-10A test called for 85% relative humidity at a temperature of 90°F during the hot soak. When the facility was operating at the limit of allowed tolerances, it sometimes produced an RH of 90%. When this condition was encountered after a cold flight (0 to -16°F), as it might be by an A-10 descending from cross-country altitude near Myrtle Beach or other tropical-subtropical base, the diplexer and diversity switch were coated inside and out with water and a loss of output resulted. Water inside the equipment bays and IFFs on landing was confirmed by Myrtle Beach personnel.

These four examples - the broken shock mount, the frequency shift, the condensation failure, and the RETOK reduction study - show how a CERT can identify "nonfailure," CND, and RETOK problems in system hardware.

6. Test Equipment Checkout

Perhaps the biggest advantage of a CERT is that you can have two different environmental reliability demonstrations for the price of one. All CERTs would use the authorized flight line and field shop test equipment and sets for checkout and repair of the test articles. Most, if not all, would use these same items for operation as well. In all of the CERT evaluation program tests, failure data on the test equipment/sets was accumulated. This data pinpointed several items that exhibited poor reliability when compared to the average of all items used. One example is the navigation test set that exhibited such severe attenuator hand-effects that the set was almost unusable for sensitivity checks. This problem was temporarily eliminated by PMEL on some of the sets. Another example is the counter-converter that produced false counts under simultaneous conditions of near maximum ambient temperature (55°F) and near maximum input level. Failure information on test sets is not generally available, so confirmation of the hand-effect problem was sought from field personnel and obtained.

The test planning stage of CERTs has also provided information about the test equipment specified for field use. In planning for a test of a communications radio, the test engineer found:

a) That R.F. pads specified were not available, had not been available a year before when the T.O. was published, and probably were not available when the T.O. was written.

b) That laboratory-grade equipment was specified when service-grade equipment, proven by commercial usage on equivalent land mobile service equipment, was available at considerably less cost. One example is the use of laboratory-quality signal generators and modulation monitors instead of commercial communications monitors.

c) That the service-grade equipment, designed for more specific purposes, is easier to operate than the more flexible laboratory-grade equipment. An excellent example of this finding as well as of b) above would be using a commercial signal-to-noise ratio measurement set sold as the "Sineadder" rather than a laboratory distortion analyzer.

These examples show how a CERT gives an opportunity for thorough evaluation of the test sets and equipment used for flight line or field maintenance.

In a recent address to the IEEE at NAECON, ASD Commander, General Skantze, pointed out the need for moving reliability, maintainability, and product assurance considerations to an earlier time in the acquisition process. The hidden benefits of a CERT are that it gives the opportunity to examine many aspects of the reliability/maintainability question that are often neglected before a buy decision is made. A CERT, whether used as a reliability growth or demonstration test, can provide accurate data to support:

Life Cycle Costing.

System Hardware Improvement.

Maintenance Support Hardware Evaluation and Improvement.

System and Maintenance Support Software Evaluation and Improvement.

<u>OTHER USES OF THE CERT CONCEPT</u>

Based on evaluation program results, the CERT concept recommends itself for use in:

Qualification Testing

Acceptance Testing

of parts, modules, and systems. A very important special case of acceptance testing is the acceptance of a product improvement. Consider the case of the series of micro-miniature connectors that was <u>improved</u> by replacing the easily broken plastic mounting ring with one made of metal. Another change had to be made when it was discovered that the metal ring caused excessive condensation and corrosion inside the connector. A short-duration Combined Environment Test (CET) could have determined this before, rather than after, acceptance and deployment. In most qualification and acceptance testing, combinations of <u>realistic</u> environmental parameter extremes, rather than mission profile combinations, should provide the most useable results.

Combined Environments in acceptance and qualification testing offers many of the same advantages realized in a CERT. The following are especially worthy of note:

You save time -	as compared to sequential tests on the same articles.
You save money -	on test article and facility operating cost as compared to application of single environments to different test articles.
You gain synergy -	of whatever type and in whatever amount exists during your profiles.

Why take the time to run individually the several environmental stress tests such as temperature cycling, humidity exposure, vibration exposure, altitude cycling, and electrical discharge exposure that could be combined? If the article passes the CET, you know that the article will survive not only the individual environmental parameters but their synergistic force as well. And if the article fails, the cause, <u>if needed</u>, will be apparent in most, if not all, carefully designed tests.

SUMMARY

The hidden benefits of a CERT are that it reveals:

System Software Problems

Defects in Maintenance Support Hardware and Software

High CND Rate Systems.

It does this while giving you an accurate value for system hardware failure rates and modes.

In closing, the author would like to point out his agreement with those who say that reliability and maintainability are obtained <u>only</u> by applying your "best engineering practices" during design.

Then . . . . .

You test . . . . .

To be certain . . . . .

That your design judgments were accurate and economical, that quality is maintained in production, and to develop the next generation of "best engineering practices."

The evidence shows that the CERT concept provides the most accurate, most comprehensive, most economical means, presently available, to do this testing.

BIOGRAPHY

Ronald D. von Rohr is a test engineer for the AFWAL CERT facilities at Wright-Patterson AFB, Ohio. He has planned, conducted, and/or reported the results of three CERT evaluation program tests since his assignment to the facility in 1979. During his earlier military service he maintained airborne navigation systems and taught navigation equipment repairman courses at Keesler AFB, Mississippi.

BENEFITS OF MISSION PROFILE TESTING

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INTRODUCTION

The level of reliability achieved by deployed avionics equipment has generally been less than desired by the acquisition, logistics and using commands. Studies have shown that there are numerous and often overlapping factors that contribute to this problem (Refs. 1,2 and 3). Additionally, these factors are not independent of one another so that it is difficult to easily identify how much avionics equipment unreliability is due to any one specific factor.

One of the studies grouped these numerous factors into the following six broad basic areas (Ref. 3):

1. Reliability testing and analysis
2. Field data collection
3. Reliability management and documentation
4. Reliability design
5. Reliability training
6. Software reliability.

It is the thrust of this paper to show how the use of a properly structured testing program will cause significant equipment reliability improvements in many of these basic areas. The paper will discuss these improvements in terms that are meaningful and measurable to the decision makers that exist in the life cycle of a typical avionics equipment system. For the sake of discussion, these decision makers can be represented as the acquisitor, logistician, operational user, and command level of the avionics equipment system. To understand the perspective of these decision makers, the next section outlines what is meaningful and generally used to measure their performance. The primary drivers for these decision makers are:

Acquisitor: The primary drivers in an equipment acquisition program have been performance, cost and schedule (Ref. 4). Reliability may become a major consideration because of the recent issuance of DoD Directive 5000.40.

Logistician: The primary drivers are providing, when and where needed, adequate quantities of support equipment, spare parts, trained personnel and equipment.

Operational User: The primary drivers are to have avionics equipment that have high levels of availability and sustainability that allow the accomplishment of the required missions.

Command Level: The primary drivers are to produce more operational capability at a minimum overall life-cycle cost.

ACQUISITOR

The acquisitor decision maker generally wants to reduce the risks of schedule, resources, or technical problems. This means that any deficiencies that slip through the design process need to be identified as early as possible since it is easier and cheaper to change paper designs than rework already built hardware. There are two ways of reducing the probability that a design defect will go into hardware: (1) strengthen the design techniques and thereby reduce the number of design defects, and (2) strengthen the evaluation techniques.

Electronic hardware technology is constantly changing and the development of necessary reliability data base on new technology components is not keeping pace. Additionally, the increased complexity of modern avionics increases the chance of undetected design deficiencies occurring in a design. Both of these factors tend to suggest that to reduce program risk, techniques in addition to design are needed. This conclusion is supported by NASA Apollo spacecraft experience: "The single most important factor leading to the high degree of reliability of the Apollo spacecraft was the tremendous depth and breadth of the test activity." (Ref. 5).

The thrust of such testing should be to demonstrate that the design is proper and will perform properly in all deployment environments, thereby reducing risks of schedule and resources overruns.

LOGISTICIAN

The logistician has a different view of reliability than the acquisitor. Resources are the driving factor behind the logistician. It is his job to maintain adequate spares to the operational units and the necessary support equipment needed for maintenance. He sees the reliability of a new system as how many spares must be obtained.

His criteria for failure classification are primarily resource and operation impact oriented. This is in contrast to the acquisition community which is primarily mission success oriented. To the acquisition world, the reliability of an avionics system is judged as if the system was its own separate entity. Thus, any evidence of externally induced failures or secondary failures generally would be classified as nonrelevant. Yet, these same failures would be classified as relevant by the logistics or operational community because the failure consumed resources and reduced operational capability. With his budget constraints, the logistician needs to be able to know the number of spares and support equipment he must initially obtain in order to support the operational units. He needs to know from a reliability test a fairly accurate MTBF (mean time between failure) and what will be failing in order to allocate his limited funds toward spares and support costs. Therefore, the logistician views the success of a reliability test concept by its ability to provide data to help him accurately predict his sparing requirements.

OPERATIONAL USER

The operational user considers reliability as to how it impacts maintainability and availability of the total weapons system. A maintenance squadron's scorecard is determined by how many aircraft are operationally

ready at any given time. Reliability information to this community is used to determine a system's availability as it impacts downtime per sortie and the resources needed to handle maintenance events. It takes time and manpower to troubleshoot,diagnose and repair failures; and the more complicated the equipment, the longer it takes to repair. The time spent on avionics equipment maintenance is time the aircraft is not available to perform its mission. Therefore, the operational user determines the reliability of a system by the amount of aircraft downtime it causes. The allocation of resources, tools, equipment, skills and manpower at the base level is performed in order to produce a maintenance system tailored to produce more combat sorties with the available resources. The impact of reliability testing on aircraft downtime is the criterion the operating commands would use to judge its success rate.

COMMAND LEVEL

The decision maker at the command level sees the big picture. He wants to provide the operational users what they need at minimum overall (life cycle) cost. Therefore, the command level decision maker tries to balance the resources spent by the acquisitor, logistician and operational user to minimize the total cost of the avionics equipment system. The ability of improved testing to help reduce overall avionics equipment costs would be how the decision maker at command level would view improved testing.

BASIS FOR MISSION PROFILE
COMBINED ENVIRONMENT RELIABILITY TEST (CERT)

Analysis of environmental data show that the environmental conditions of temperature, humidity, altitude, vibration and cooling airflow do not generally remain constant throughout an aircraft's mission. In fact, strong correlation exists between the mission of an aircraft and the environmental stress combinations that are imposed upon its avionics at any given instant of time throughout its flight. This correlation between the aircraft flight conditions and the environment in which its avionics must

function suggests that the environmental combinations should be time sequenced in a test similar to how the aircraft is flown so that the resultant laboratory test conditions would be more representative of the field environment (Refs 2,6,7). This concept has been called combined environment profile testing. This concept forms the basis for the CERT approach.

Combinations of environmental conditions characteristic of those that occur during aircraft ground park, takeoff, cruise, combat, and other major flight conditions are put together into a test sequence that follows the order in which they would occur during a typical aircraft mission. Therefore, the equipment acts as if it is actually undergoing a flight during the combined environment mission profile test sequence. Thus, the behavior of the equipment under test should closely approach its field performance.

Benefits to Acquisition Decision Maker

Avionics technology is constantly changing. Generally, there is very little historical data on how new technology electronic components behave under the kinds of dynamic environmental stresses to the experienced in operational deployment. Therefore, evaluation of the anticipated designs need to be accomplished early in the design process. Additionally, these tests need to be realistic so that there is a high degree of confidence by the decision maker that the identified defects, if not corrected, would occur in the deployment environment.

CERT has such credibility. This comes about because, in CERT, the environmental stresses are combined and sequenced in a realistic temporal manner as if the test item was in actual flight. Additionally, the approach has several conceptual advances that tend to help give credibility to a decision maker: (1) the environmental stresses occur simultaneously as if in deployment, (2) no engineering protest judgement needs to be made as

to which order or sequence of separate single environment tests would be appropriate, and (3) test conditions can be directly related to operational usage with no artificial raising of test levels above deployment stress levels.

A way of utilizing CERT to accomplish this objective of early identification of deficiencies, is through a test-analyze-fix growth test program which uses CERT environmental test conditions. Analysis of CERT growth programs used on five different avionics equipment systems found that the reliability of these equipments increased at a rate of 300 percent for each increase in order of magnitude in number of test hours (Refs. 9 and 10). This significant increase in equipment reliability occurred in less than four calendar months. In fact, the savings in equipment development time of two to four years have been projected by a major electronics equipment contractor (Ref 17). These analyses were used as a basis for company funding for installation of a CERT facility.

A CERT growth test in addition to providing highly credible results in a short period of time can provide significant other savings through the deletion of separate individual tests. For example, one Air Force equipment acquisition program eliminated seven separate single environmental qualification tests and the normal reliability demonstration test with a single combined environment mission profile test (Ref. 9). The cost savings realized by this approach can be estimated using the HQ Air Force Systems Command (AFSC/XR) figures for test costs (Ref. 11). Table I shows the cost savings based on these cost factors and the cost to conduct a CERT growth test of approximately 2,000 test hours. The cost savings are shown in terms of dollars saved and number of calendar days. After the approximately 2,000 hours of CERT growth testing, the same serial nummber units were used directly in additional flight testing.

The data in Table I are from a competitive CERT growth program with three separate contractors being tested at a single site. The overall cost effectiveness of this approach to the acquisition decision maker is summarized in Table II. The savings of over $800,000 are dollars that the acquisition decision maker can reprogram or turn back to the Air Force.

With this reduced expenditure of resources in the acquisition phase of this program, there is no apparent compromise in fielded system performance as demonstrated by its recorded 1192-hour field MTBF, which is 2.4 times the design goal of 500-hour MTBF.

The productivity of this approach has been recognized and has been used on another Air Force program (Ref. 10) and will be used on the Global Positioning Satellite (GPS) system user equipment.

Benefits to Logistician

The MTBF of a new system is important to a logistician. This value is used as a major consideration in the calculations to determine the number of spares to be procured. It is the logistician's job to ensure that adequate resources are made available to each operational unit. Otherwise, a unit with inadequate resources is placed on NORS (not operationally ready spares) status. This impacts the operational readiness of the Air Force fleet. CERT can be of great benefit to the logistician by more closely predicting the MTBF of a new system. Previous reliability tests have demonstrated an unrealistic MTBF which has led to inadequate spares procurement. CERT has shown a much closer correlation between the laboratory test and field conditions. By more closely duplicating the aircraft's operational environment, CERT gives a more realistic estimate of a new system's MTBF (Ref. 12).

Air Force laboratory tests have demonstrated that mission profile testing shows MTBF values within 70% of actual field data, which leads to a 1.9 to 1.0 laboratory to field ratio. By predicting a viable MTBF value, mission profile testing will enable the logistician to know the true number of spares and resources he needs to obtain to fully support operational units without undergoing NORS status. This also will enable him to properly allocate and utilize his financial resources to the fullest capability.

A recent study found that a CERT of 1200 hours, typically three months, on the average will identify sufficient numbers of hardware defi ciencies to make such a test cost effective. Within two years, it will return, in reduced logistics costs, the investment in the costs associated with conducting the CERT, performng failure analysis, designing corrective actions, confirming corrective actions, and implementing redesign in the production run (Ref. 13). This suggests that an investment in a few months of CERT on even already deployed systems can significantly cut its operating and support (O&S) costs.

Benefits to Operational User

The operational user has different requirements that reliability testing needs to address. A maintenance unit must keep the operational squadrons in readiness by keeping the downtime between sorties to a minimum. Therefore, any system requiring repair and corrective actions prohibits the operational user from achieving his goal.

It takes time and resources to perform maintenance actions on equipment, and not all reported failures are identifiable. According to a recent report (Ref 14), approximately one-third of all flight failures cannot be confirmed at base or depot repair facilities. These intermittent, or CNDs (cannot duplicate), are typically returned to the spares inventory where they may re-occur. These intermittent failures constitute a drain on resources, increase spares requirements, and decrease mission success rates. Avionics equipment is pulled and sent back to the depot for repair that may not need repair or could have been corrected at the base. This creates a congestion in the supply pipeline by increasing the spares requirement. It also drains the operational user by repetitious removal of equipment, excess maintenance, and frustration at not properly diagnosing and correcting the problem. Mission profile testing can help correct this by showing potential design deficiencies in new avionics systems which can be corrected before it reaches the operational field.

During the CERT Evaluation Program, mission profile testing exhibited failures in which 41 percent were intermittent. By correcting these problems early in the acquisition of a new system, the CND rate can be decreased significantly. This will enable the operational user to utilize his resources efficiently in correcting hard failures quickly and effectively.

Benefits to Command Level

The decision maker at the command level is interested in obtaining the most effective utilization of resources spent by the acquisitor, logistician and operational user. Studies have shown that the earlier the testing is done in the equipment development phase, the more leverage there is for reduction of equipment operation and support (O&S) costs (Ref. 7). Programs, such as summarized in Table II, have shown that a CERT growth test can significantly reduce acquisition costs over traditional approaches of waiting until later in the development cycle. The leverage of cost reduction benefits everyone in the decision making process by reducing overall equipment costs.

SUMMARY

The perspective of the different decision makers in the life-cycle of a typical avionics equipment are focused on factors that are measurable and meaningful during their periods of accountability. To cause change in equipment reliability or quality requires either changing the factors on which each decision maker is evaluated or to develop tools that improve his performance when measured against the established performance factors. This paper discusses how a combined environments mission profile (i. e. CERT) test, when used as a test-analyze-fix growth test program in the acquisition process, benefits all the decision makers during the life-cycle of the equipment.

TABLE I. SAVINGS AVAILABLE USING A CERT GROWTH TEST

TEST DELETED/REPLACED	SAVINGS
Deleted seven separate environmental qualification tests	- $195,400
Deleted reliability demonstration test (5000 hrs @ $170/hr)	- 850,000
Replace with a single CERT growth test (Ref. 15)	+ 230,000
COST SAVINGS	$815,400
Deleted seven separate environmental qualification tests	- 129 days
Deleted reliability demonstration test	- 125 days
Replace with a single CERT growth test (Ref. 9)	+ 50 days
NUMBER OF DAYS SAVED	204 days

TABLE II. TOTAL ACQUISITION PROGRAM COST COMPARISONS

ACTIVITY	CERT PROGRAM COST	TRADITIONAL PROGRAM COST
1. Design and build seven preproduction units, support government-run tests, do failure analysis, perform corrective actions, provide engineering data.	$1,770,000	$1,770,000
Contractor A - $279,000 (Ref. 16) Contractor B - $382,000 Contractor C - $659,000		
2. Conduct CERT growth test on two units of each contractor	$ 230,000	- -
3. Traditional reliability demonstration and environmental qualification tests	- -	$1,045,000
4. Summary	$2,000,000	$2,815,000
Program Savings to Acquisition Decision Maker = 41%		

TABLE III. BENEFITS TO DECISION MAKERS USING A COMBINED ENVIRONMENT MISSION PROFILE TEST (CERT).

DECISION MAKER	BENEFIT TO BE GAINED
Acquisitor	Reduce number of tests Reduce duration of testing Reduce test associated costs Rapidly improve product
Logistician	Predict sparing needs more accurately Reduce maintenance manpower Improve support to operational user
Operational User	Reduce CND (cannot duplicate) Improve readiness Reduce maintenance manpower
Command Level	Reduce life-cycle cost

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AN APPROACH TO ASSESSING THE AIR FORCE
CERT FACILITIES NEEDS

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FOREWORD

The Air Force need for CERT facilities is developed from an analysis of the ongoing and planned avionics development and acquisition programs. These requirements are compared to the available Air Force and Industry CERT facilities developed from a government/industry survey conducted by TASC to assess the future need for additional CERT facilities. A listing of the capabilities of those CERT facilities responding to the survey is presented. A recommendation is made of how CERT resources should be applied and how additional needs should be accommodated.

1. INTRODUCTION

The Department of Defense (DoD) has placed emphasis on improvement in reliability by the application of Combined Environment Reliability Test (CERT) to the detection of design deficiencies, weak parts, and workmanship defects. DoD Directive 5000.40 Reliability and Maintainability requires that "performance, reliability and environmental stress testing shall be combined, and types of environmental stress may be combined insofar as practical" (Ref. 1). The directive requires R&M growth during full-scale development, concurrent development and production, and during initial deployment. This growth is to be provided by a test and correction program often referred to as Test, Analyze And Fix (TAAF). CERT or Mission Profile Testing is a more realistic and effective testing approach than the traditional sequential environmental stress testing in uncovering faults that occur in the operational environment.

This paper addresses the Air Force CERT testing requirements for currently planned avionics programs and compares them to the available Air Force and Industry capability. An approach toward matching resources to requirements is suggested.

2. BACKGROUND

It has been recognized for many years that the reliability of avionics equipment, as reported for field operations, is generally much lower than predicted and laboratory demonstrated reliability. This has been attributed to the lack of correlation between the actual flight environment and the laboratory environmental conditions applied during test. Prather and Earls (Ref. 2) reported the results of an Air Force Flight Dynamics Laboratory program which established a high correlation between failures observed during operations and those observed during a Combined Environment Reliability Test (CERT) conducted on a multi-mode, dual channel radar subsystem employed in a high performance aircraft. This success lead to the initiation of an Air Force CERT Evaluation Program to assess the technical merit of combined environment reliability testing, evaluate the cost effectiveness of this type of testing, and provide implementation and planning. The Program is a joint effort of three AFSC organizations at Wright-Patterson AFB: Aeronautical Systems Division's PRAM Program Office, ASD Directorate of Engineering and AF Wright Aeronautical Laboratories. The PRAM Program Office provides overall direction to the program. The AF Flight Dynamics Laboratory within AFWAL performs the laboratory technical effort in acquiring chambers, formulating test procedures and conducting tests. Engineering support to specific tests is provided by ASD Directorate of Engineering (Ref. 6).

Since environments can be combined in various combinations and the inclusion of altitude significantly increases cost without necessarily improving the results, the CERT evaluation program evaluated three test sequences: full CERT, CERT without altitude and MIL-STD-781C Appendix B (Ref. 4). Results from each of these test sequences were compared with field experience to establish the relative effectiveness of each sequence. Continued CERT evaluation has shown a consistent correlation between field experience and full CERT (Ref. 5). A recent comparison of the three testing methods applied to an IFF system showed the full CERT and CERT without altitude to produce the same MTBF results (Ref. 6).

The CERT evaluation program is nearing its conclusion with a final report scheduled to be published in the near future. To date, CERT's ability to stimulate field failure modes and rates has been established and accepted. The benefits of CERT are more diffuse. It has been shown that CERT of Mission Profile Testing has benefits to the Acquisition Agent, Logistician, Operational User and Command Level (Ref. 7).

The Navy has been using CERT for monitoring production quality on captive carry Air Force and Navy missiles for many years. The results correlate with field experience and are generally cheaper and quicker than divided environment tests (Ref. 8).

Sufficient CERT evaluation data have been collected to permit the development of recommendations concerning the use of CERT in the acquisition process. The DoD CERT Workshop on 2-4 June 1981 is being planned to address this issue. This paper attempts to project the Air Force need for CERT facilities and to compare it with existing Air Force and Industry CERT capabilities.

3. OVERALL APPROACH

To develop the Air Force need for CERT facilities, this paper analyzes the Air Force's planned and ongoing development and production avionics programs requiring CERT. The Institute of Environmental Sciences Recommended Practices for Environmental Test Program Management is used as the basis for determining the application of CERT (Ref. 9). Both Air Force Flight Dynamics Laboratory and Hughes Aircraft Company experience in CERT testing are used as the basis of facilities utilization (Ref. 10).

Having projected the need for CERT facilities, this need is compared to the available resources resulting from the Industry/Government Facilities Survey for Combined Environment Reliability Testing (CERT), July 1980 conducted by TASC for the Air Force. Suggestions are made as to how the available CERT resources might best be used and augmented to meet the total need.

3.1 Air Force Planned Avionics Development

The Air Force Avionics Master Plan was reviewed to identify programs and time phasing for development and production (Ref. 11). Some 39 programs over five mission areas were identified. Tables I through V cover the different mission areas. The horizontal bars represent active programs during the interval of interest. The clear bars represent Full-Scale Engineering Development and the hatch marked bars represent Production. The numbers superimposed on the clear bars represent the projected assignment of a fulltime CERT facility. The total opposite the FSED at the foot of each column consists of two numbers separated by a slash mark. The first number is the total of active programs. The second number is the total of full time CERT facilities. The total number of active production programs is on the bottom line. Those programs listed as avionics contained classified information. Table VI contains a summary of FSED and Production programs active during each year. During the period 1982 through 1986, an average of 27 programs will require some form of CERT testing including TAAF, Reliability Demonstration or Production Acceptance.

3.2 Application of CERT to an Avionics Program

This section develops an estimate of the CERT testing that would be applied to a typical avionics program. The Institute of Environmental Sciences proposed recommended practice on Environmental Test Program Management is used as a basis of identifying the types of CERT tests that would be applied (Ref. 9). The testing activities which are the major contributors to CERT test duration are identified and estimates are made of typical test durations. These test durations are used as a basis of estimating the total Air Force CERT requirements.

Table VII summarizes the characteristics of environmental testing. The types of testing which are the major time consumers are: Test Analyze and Fix (TAAF), Reliability Demonstration (Rel Demo) and Production Acceptance. The reliability improvement trend with environmental testing is shown in Figure 1.

TAAF and Rel Demo are part of Full-Scale Engineering Development and Production acceptance is part of Production. Production Screening, though not a large time consumer, is a significant test for removing "infant mortality" type failures and reducing the number of field failures. Production Screening typically uses combined temperature and vibration in a dedicated screening setup.

Each avionics program will require a TAAF and Rel Demo during full-scale development followed by Production Acceptance testing during production. Although the CERT testing requirements for each avionics system are unique and would be tailored to the specific mission profile, the approach used in this analysis is to develop standard testing times for a typical avionics system. Test duration estimates will now be developd for TAAF, Rel Demo and Production Acceptance.

3.2.1 TAAF

TAAF test durations for a typical avionics program are developed in this section. Design guidelines for TAAF programs are provided in the Military Standard for Reliability Growth Testing (Ref. 12).

The Duane reliability growth model is used in planning a TAAF program. An example of planning TAAF test duration is provided in Figure 2. In this example, the predicted MTBF (θ_P) is 1000 hours and the required MTBF (θ_R) is 800 hours. A growth rate (α) of .5 is assumed. The initial point of the cumulative MTBF line is plotted at MTBF = 10% θ_P or 100 hours and total test time of 50% θ_P or 500 hours. The cumulative MTBF line is then drawn with a slope of α = .5. The current MTBF line is drawn parallel to the cumulative MTBF line offset by $1/(1 - \alpha) = 2$. Where the current MTBF line intersects the required MTBF line an ordinate is dropped to the horizontal. A total test time of 8000 hours is required.

To assist in estimating test durations, a family of reliability growth graphs similar to the one illustrated in the example of Figure 2 was developed. Two tables were developed from the family of graphs. Table VIII tabulates the MTBF growth factor as a function of α for ten times increase in test

duration (5 θ_p). Table IX tabulates the test duration in hours and multiples of θ_p as a function of α for an eight times increase in MTBF (0.8 θ_p). If an operational MTBF (θ_R) of 200 hours is desired of a complex avionics subsystem and the predicted MTBF (θ_p) is 250 then the MTBF plot begins at ($\theta_p/2$) 125 hour test time and an MTBF ($\theta_p/10$) of 25 hours. An eight times growth in MTBF is desired. Reference to Table IX shows that if α is between .5 and .6, the 1250 hour test duration can be expected to produce the desired 200 hour MTBF. To achieve a 400 hour MTBF with a predicted MTBF of 500 hours and an α between .5 and .6 requires a 2500 hour test duration. Reference to Table IX shows that if α is .5, the duration is eight times the predicted MTBF. TAAF test durations can thus be expected to be between 3.5 to 25 times the predicted MTBF. For analysis purposes a factor of 10 will be assumed. This corresponds to an α of .55.

Avionics MTBFs can be expected to vary from a low of 25 hours to a high of over 1000 hours for simpler subsystems. For purposes of analysis, a typical MTBF requirement of 200 hours will be assumed. Calculations of test times will be based on this number.

3.2.2 Reliability Design Qualification - Rel Demo

Rel Demo test durations for a typical avionics program are developed in this section. Design guidelines for reliability testing for qualification and acceptance are provided in MIL-STD-781C (Ref. 13). The standard is organized into test plans according to Nominal Decision risks and Discrimination ratio. A selection of 10% risk and a Discrimination ratio of 3 results in a practical risk with a minimum of test time. The minimum test time (Test Plan XVC MIL-STD-781C) is 9.3 times the minimum acceptable MTBF. Rel-Demo test times will run six to ten times the minimum acceptable MTBF to be demonstrated depending on the choice of test and risk. For purposes of analysis a factor of 10 will be assumed.

3.2.3 Production Acceptance Testing

Production Acceptance test durations for a typical avionics program are developed in this section. Production Acceptance testing typically is done on a sampling basis. The test plans are established in accordance with MIL-STD-781C. The selection of a test plan is the same as for Rel Demo. Typically, test times run six to ten times the minimum MTBF to be demonstrated. For purposes of analysis a factor of 10 will be assumed.

3.2.4 Combined Testing Requirements

This section combines the test durations of the TAAF, Rel Demo and Production Acceptance, and relates them to CERT facilities utilization. By testing more than a single unit in a test chamber the calendar test duration can be significantly reduced. For example, two test samples in a chamber reduces the calendar time by half. For TAAF and Rel Demo, test resources are difficult to acquire; therefore, two test samples will be assumed. It is impractical to have only one sample because any failure disrupts the testing. Table X provides test durations for each type of test for a 200 hour MTBF requirement. It will be assumed that two test articles will be used as a minimum and that the two articles will be tested together in the same chamber.

Air Force CERT testing experience (Ref. 10, pp. 70-71) yields an average chamber utilization of 7 hours/day. Of that, only 4.25 hours/day represented equipment "ON" time. This "ON" time is the only time that would contribute to an MTBF determination. The 4.25 hours/day is 18% utilization of the test chamber per day. Hughes' CERT and MIL-STD-781B testing experience (Ref. 10, pp. 73) provides an average chamber utilization of 1.5 hours/day or 6.4% utilization. The *industry utilization experience* is expectedly lower than that of the government experience because, in the government, case mature equipments were being tested. In the event of a failure a replacement unit was usually available to replace the failed unit. In the case of industry testing, in the event of a failure the chamber remained idle until the cause of failure could be analyzed and corrected.

Notwithstanding the rationale for why industry experience was lower than the government's, it appears reasonable to assume higher utilization factors are practicable for both industry and government. It will be assumed that both government and industry will achieve the same utilization efficiency for each class of test since each will face similar delays when failures occur. Based on these assumptions, the test durations for a 200 hour required MTBF would be as shown in Table XI. A utilization efficiency of 25% is assumed during Rel Demo because the experience gained during TAAF should permit more efficient utilization of the test chamber. A utilization of 66% is assumed for Production Acceptance because this is a repetitive test and problems are typically ironed out during the initial Production Acceptance testing. The 66% is consistent with Air Force planning for CERT testing.

Typically, Rel Demos need to be repeated because of avionics equipment failures, which would double the times shown in Table XI. A complete TAAF could take a year; however, most programs depend on the Rel Demo to demonstrate that corrective action has been accomplished. If corrections are not incorporated during TAAF, test time for TAAF can be reduced but Rel Demo will increase in duration. Scheduling of Production Acceptance testing depends on production rates. Sufficient units need to be produced so that the sample size is only a small fraction of the batch. For analysis purposes, it will be assumed that Production Acceptance testing will be initiated quarterly. This means that Production Acceptance testing requires a chamber two-thirds of the time.

3.3 Projected Air Force CERT Facilities Requirements

This section develops estimates of the number of Air force avionics programs that are in Full-Cycle Engineering Development or Production that would require CERT testing. Using the data in Tables I through V and assigning a CERT facility during each of the last two or three years of FSED and a CERT facility during each year a program is in production, the data in Figure 3 were developed. Figure 3 provides the number of fulltime CERT facilities required by the Air Force. Not reflected in this estimate is the condition that some programs will have two contractors doing parallel competitive developments during FSED.

3.4 Available CERT Facilities

Information on available facilities was developed from responses to the Industry/Government facilities survey questionnaire, discussions with industry and government personnel, and published information (Ref. 14). The Industry/Government facilities survey was conducted for the Air Force by TASC. Questionnaires were sent to a selected list of companies who were producers or users of CERT facilities.

3.4.1 Government CERT Facilities

The Air Force CERT Facilities located at Wright-Patterson AFB, Dayton, Ohio are listed in Table XIIa. Other Government facilities located at Holloman AFB, Alamogordo, New Mexico and the Pacific Missile Test Center, Pt. Mugu, California are listed in Table XIIb and c. The Pacific Missile Test Center is a Navy facility which tests the majority of the captive carry tactical missiles used jointly by the Air Force and Navy.

3.4.2 Industry CERT Facilities

This section tabulates the results of the industry responses to the Industry/Government survey conducted by TASC for the Air Force. Only those industry respondees having CERT I or CERT II facilities are listed in Table XIII. CERT I has a combined environment capability including altitude and CERT II is the same without altitude. A sample of a complete questionnaire is provided in Table XIIb. The tabulated data in Table XIII represents only a portion of the industry CERT facilities since a number of companies with extensive CERT experience and capability did not respond. All of the tabulated industry respondees have the capability to simulate mission profiles.

3.5 Matching CERT Resources to Requirements

This section compares the Air Force CERT facilities requirements developed in Section 3.3 with the resources identified in Section 3.4. If we assume that industry CERT facilities would be used for TAAF and most Rel Demos, then the identified requirements from Figure 3 range from 2 to 19. The average requirement for the period FY82-86 is 14. This compares favorably with survey results which in a partial response identifies 14 companies with CERT capability.

If it is assumed that the Air Force will conduct Production Acceptance testing as part of a Production Acceptance Test and Evaluation (PATE) program then, referring to Figure 3, the requirement for CERT facilities increases to 9 by FY86. Beginning in FY83, when the requirement is for 4 CERT facili-

ties, the Air Force capabilities would need to be augmented. If the Air Force cannot build up its CERT capabilities in time to meet the increased demand, it is suggested that industry facilities be used for the testing that the Air Force cannot accommodate.

In order for the Government to maintain its expertise in CERT testing, it must have facilities and use them actively. Since Product Assurance Testing is already being performed by the Production Acceptance Test and Evaluation (PATE) Department of the Navy Pacific Missile Test Center on a continuing basis, it would appear logical to expand this type of activity to cover all avionics requiring a PATE type test. It is therefore suggested that the Air Force consider undertaking the Product Acceptance Testing and Product Verification Testing whenever practical from a program viewpoint. In addition, the Air Force needs CERT facilities for Production Acceptance testing of avionics which is out of production and being modified by Government Depots.

TAAF and Rel Demo should be performed at industry facilities under the supervision and control of the Government. It is suggested that avionics developers be encouraged to develop facilities for CERT II testing (combined environments without altitude). On the average, it appears there are sufficient CERT II facilities in industry, however, they might not always be with the contractor who is responsible for the avionics development. It would be ideal if every avionics system developer had a CERT facility. Small avionics developers could use independent testing laboratories or Government facilities if the investment in CERT is beyond their resources.

4. SUMMARY

The Air Force requirement for CERT facilities was developed based on the current best thinking of Government and Industry environmental testing specialists and how CERT should best be applied during the acquisition process. The major areas for application of CERT are TAAF, Reliability Design Qualification, and Production Acceptance. The Air Force Avionics Master Plan was analyzed to identify programs that were in full scale development and/or production to determine CERT requirements in a time phased, program by program basis. The analysis resulted in top level summary of Air Force CERT needs by year. These requirements were compared to available Government and Industry CERT Facility resources. Based on a limited response survey, it appears that industry can handle the current CERT needs. The Air Force needs to increase the number of CERT facilities for Production Acceptance testing on out-of-production avionics modifications.

TABLE I. AVIONICS PROGRAM AIR-TO-SURFACE ATTACK

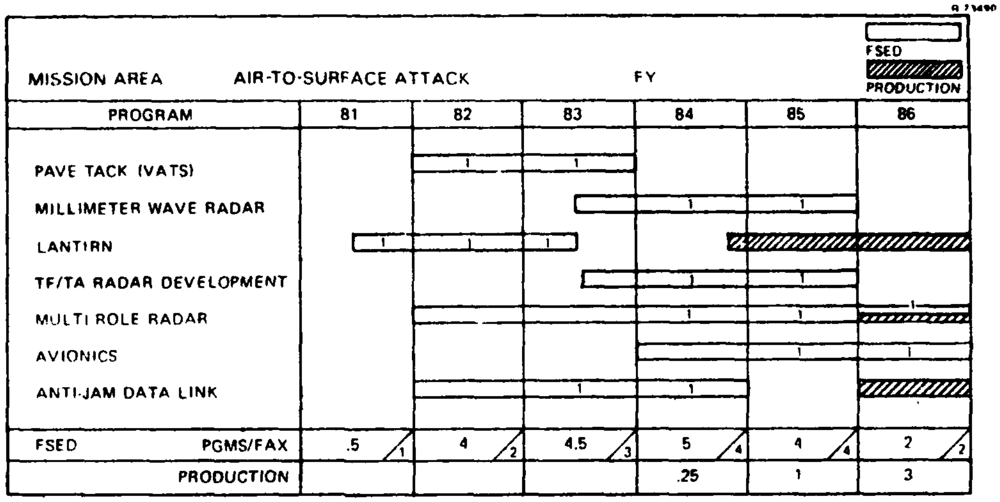

TABLE II. AVIONICS PROGRAM COMMAND, CONTROL AND COMMUNICATIONS

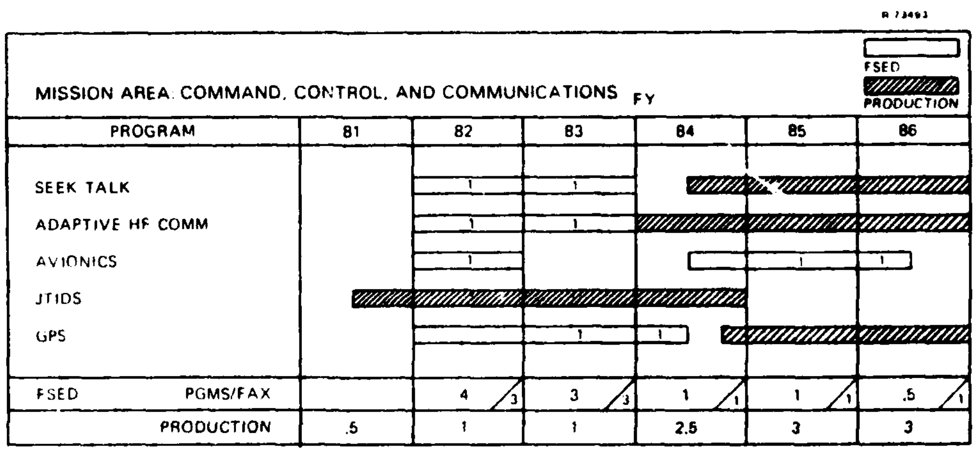

TABLE III. AVIONICS PROGRAM COUNTERAIR

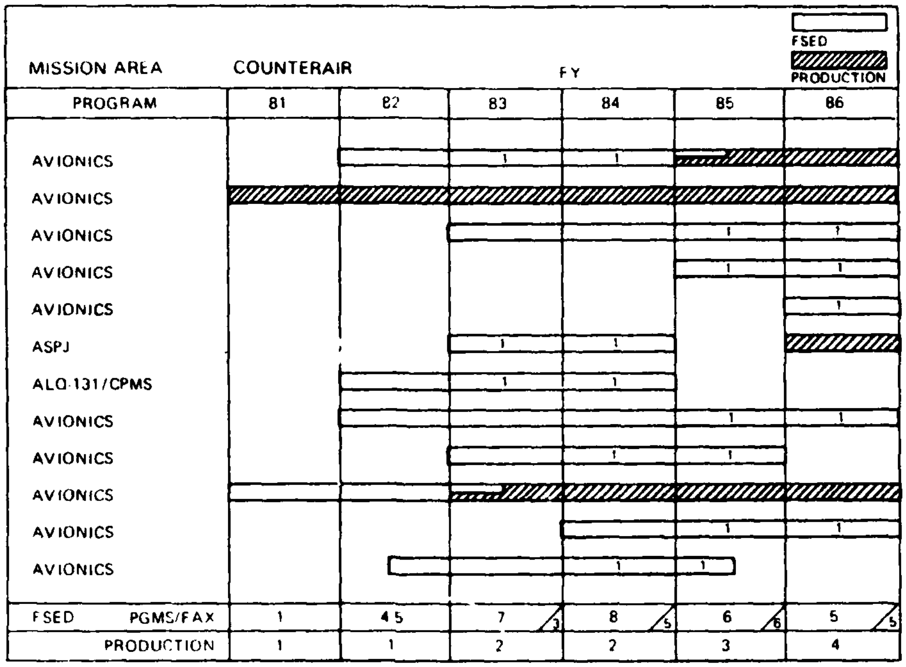

TABLE IV. AVIONICS PROGRAM RECONNAISSANCE

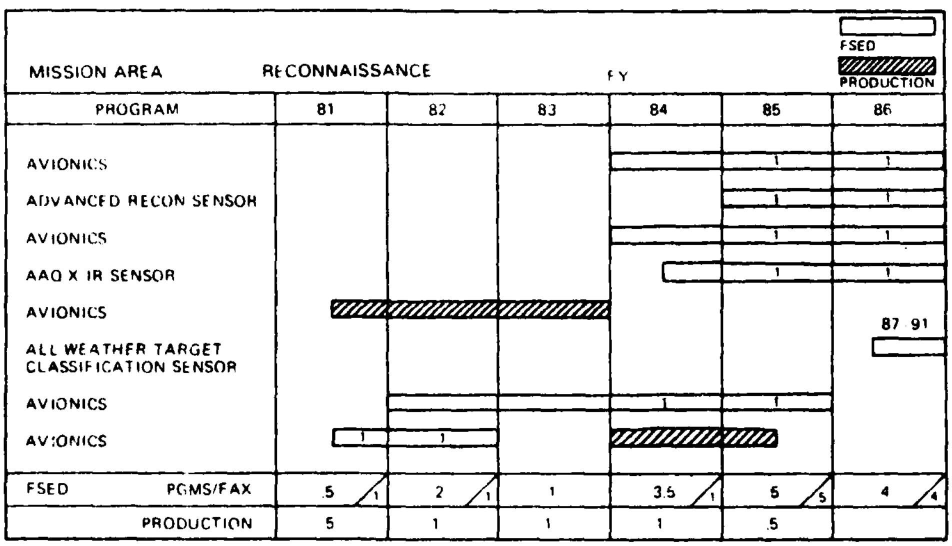

TABLE V. AVIONICS PROGRAM STRATEGIC OFFENSE

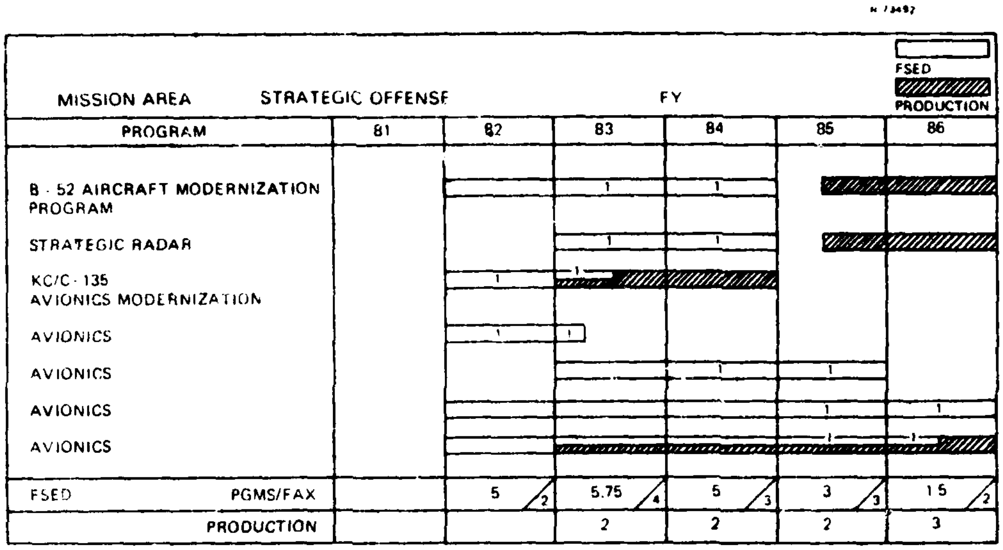

TABLE VI. AVIONICS PROGRAM SUMMARY

H 73489

TOTAL PROGRAMS 39

FSED	FY 81	82	83	84	85	86
MISSION AREA						
AIR TO SURFACE ATTACK	.5	4	4.5	5	4	2
COMMAND, CONTROL, AND COMMUNICATIONS	—	4	3	1	1	.5
COUNTERAIR	1	4.5	7	8	6	5
RECONNAISSANCE	.5	2	1	3.5	5	4
STRATEGIC OFFENSE	—	5	5.75	5	3	1.5
FSED PROGRAMS	2	19.5	21.25	22.5	19	13
PRODUCTION						
MISSION AREA						
AIR TO SURFACE ATTACK	—	—	—	.25	1	3
COMMAND, CONTROL, AND COMMUNICATIONS	.5	1	1	2.5	3	3
COUNTERAIR	1	1	2	2	3	4
RECONNAISSANCE	.5	1	1	1	1	—
STRATEGIC OFFENSE	—	—	2	2	2	3
PRODUCTION PROGRAMS	2	3	6	7.75	10	13
TOTALS	4	22.5	27.25	30.25	29	26

TABLE VII. SUMMARIZED ENVIRONMENTAL TEST CHARACTERISTICS

R-73488

1 CHARACTERISTICS	TEST TYPE: ENGRG DESIGN (DESIGN TEST DESIGN)	DESIGN EVALUATION	TAAF TEST ANAL FIX	DESIGN PROOF (ENV QUAL)	REL DEMO	PRODUCTION SCREENING WITH "BURN IN"	PRODUCTION ACCEPTANCE
2 MAJOR PURPOSE	ENGRG DESIGN INFORMATION TRADEOFF DESIGN ALTERNATIVES UNDER ENV EXPOSURE	OK S DESIGN FOR TAAF ENTREE	RELIABILITY GROWTH	CONTRACT GATE PROVES DESIGN OK TO PRODUCE	CONTRACT GATE GO AHEAD TO PROD	DISCLOSE WORKMANSHIP DEFECTS INFANT MORTALITY	VERIFY PRODUCTION QUALITY
3 PRIMARY BENEFICIARY	PRODUCER	PRODUCER	PRODUCER	CONSUMER	CONSUMER	PRODUCER	CONSUMER
4 LENGTH OF TEST(S)	MANY SHORT (days) TEST OVER SEVERAL WEEKS	SEVERAL DAYS	MONTHS	DAYS	MONTHS	HOURS	MONTHS
5 LEVEL OF ENV	ANY	SERVICE EXTREMES	TIME VARYING	SERVICE EXTREMES	VARYING	CONSTANT SUFFICIENT FOR PURPOSE	MISSION PROFILE
6 ENV DESCR	AS APPROPRIATE (STIMULATION)	(SIMULATION)	LIFE CYCLE PROFILE (SIMULATION)	SIMULATION OF EXTREMES	LIFE CYCLE PROFILE (SIMULATION)	(STIMULATION)	SIMULATION
7 SEPARATE OR COMBINED ENVIRONMENTS	SEPARATE	COMBINED	COMBINED	COMBINED AND SOME SEPARATE	COMBINED	3 OR 4 COMBINED ENVIRONMENTS	COMBINED
8 OPTIMUM ASSY LEVEL UTILITY	BLACK BOX	MODULES OR BLACK BOX	MODULES OR BLACK BOX	BLACK BOX OR SET	COMPLETE SET e.g. ANTENNA RECEIVER, AMP, DISPLAY AND CABLES	ALL	COMPLETE SET
9 RELATED STD s & SPEC s	MIL A 8870	MIL STD 810	DARCOM P702 4	MIL STD 810 MIL STD 1670	MIL STD 810	NAVMAT P 9492 IES RP	MIL STD 810
10 REL INFORMATION OUTPUT?	PROBABLY NOT	NO	YES	NO	YES	NO	YES
11 SPECIMEN CONSUMED	YES	YES	YES	YES	YES	NO	NO
12 SCHEDULE FIX AND RETEST TIME	YES	YES	YES	NO	NO	YES	NO
13 OPTIMUM CONTRACT PHASE UTILITY	V&D	V&D	FSD	FSD END	FSD END	PROD	PROD

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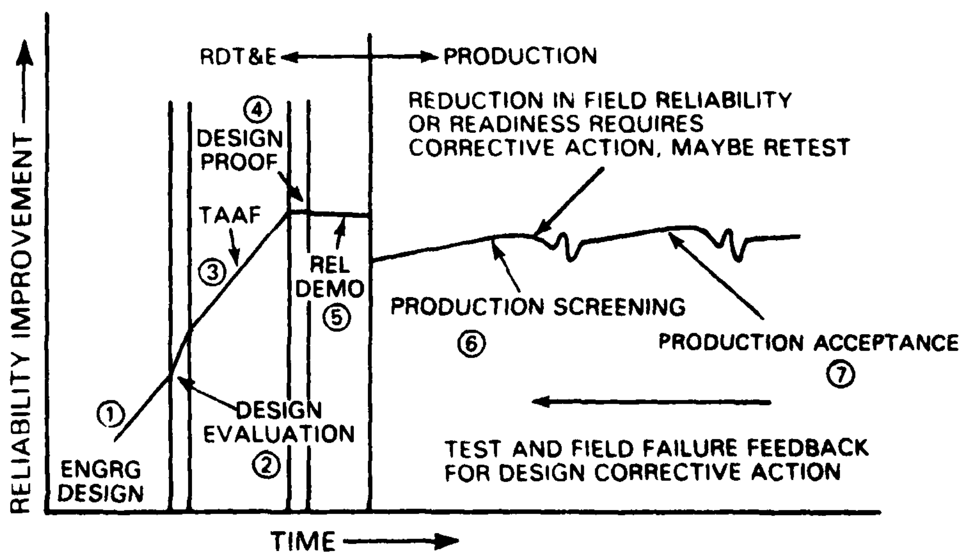

Figure 1. Reliability Improvement Trend
Environmental Testing

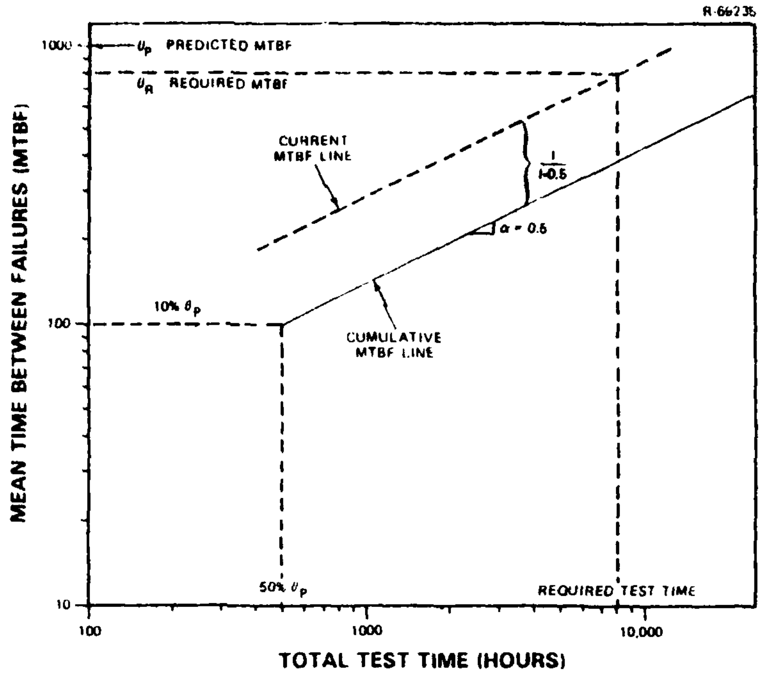

Figure 2. Example of Planning TAAF Test Duration

TABLE VIII. MTBF GROWTH FOR A TEN TIMES INCREASE IN TEST DURATION

α	MTBF FACTOR
.3	2.85
.5	6.32
.55	7.88
.6	9.95
.7	16.7

TABLE X. TEST TIMES FOR 200 HR MTBF REQUIREMENT

TYPE TEST	TEST DURATION
TAAF	2000 HR
REL DEMO	2000 HR
PRODUCTION ASSURANCE	2000 HR

TABLE XI. CALENDAR TEST DURATIONS FOR 200 HR MTBF REQUIREMENT

2 units/chamber

TYPE TEST	AF		INDUSTRY	
	DAYS	UTIL %	DAYS	UTIL %
TAAF	333	12%	333	12%
REL DEMO	167	25%	167	25%
PRODUCTION ACCEPTANCE	63	66%	63	66%

R 73495

CERT FACILITIES REQUIREMENTS

MISSION AREA	FY 81	82	83	84	85	86
AIR-TO-SURFACE	1	2	3	4	4	2
COMMAND, CONTROL, AND COMMUNICATIONS		3	3	1	1	1
COUNTERAIR			3	5	6	5
RECONNAISSANCE	1	1		1	5	4
STRATEGIC OFFENSE		2	4	3	3	2
FACILITIES REQUIRED TAAF + REL DEMO	2	8	13	14	19	14
PRODUCTION ACCEPTANCE TEST	2	2	4	5	7	9
TOTAL	4	10	17	19	26	23

Figure 3. Air Force CERT Facilities Requirement

TABLE XII. GOVERNMENT CERT FACILITIES

a) Air Force Wright Aeronautical Laboratories

CERT I

Chamber:

Size: 4 ft diameter x 5 ft long (1.2 m dia. x 1.5 m)

	Range	*Change Rate*
Altitude:	0 to 66,500 ft (20.3 km)	±38,000 ft/min (±11.6 km/min)
Temperature:	−100° to +300°F (−73° to 149°C)	±9°F/min (±5°C/min)
Humidity:	0.0005 to 0.04 Ws (Ws = lb H_2O/lb dry air)	±0.04 Ws/min

ECS Cooling Air:

Mass Flow:	0 to 5.7 lb/min (2.6 kg/min)	±170 lb/min/min (±77.3 kg/min/min)
Temperature:	−90° to +200°F (−68° to 93°C)	±100°F/min (±56°C/min)
Humidity:	0.0005 to 0.04 Ws	±0.04 Ws/min

Vibration:

Simulator: one electromagnetic shaker
Frequency: 5 to 2,000 Hz
Modes: sinusoidal or random
Limits: 1 inch (2.5 cm) P-P amplitude, 8,000 lb force (3630 kg force)

CERT II

Chamber:

Size: 7 ft diameter x 10 ft long (2.1 m dia. x 3 m)

	Range	*Change Rate*
Altitude:	0 to 70,000 ft (21.4 km)	+10,000 ft/min (3 km/min) ascending −20,000 ft/min (6.1 km/min) descending

Airflows: two independently controlled: one for bay environment, one for ECS cooling air

Airflow Capabilities (each flow):

	Range	*Change Rate*
Mass Flow:	0 to 7.5 lb/min (3.4 kg/min)	±100 lb/min/min (±45.4 kg/min/min)
Temperature:	−65° to +160°F (−54° to 71°C)	±120°F/min (±67°C/min)
Humidity*	0.00001 to 0.04 Ws	±0.04 Ws/min

Vibration:

Simulator: one electromagnetic shaker
Frequency: 5 to 2,000 Hz
Modes: sinusoidal or random
Limits: 1 inch (2.5 cm) P-P amplitude, 17,500 lb force (7950 kg force)

CERT III

Chamber:

Size: 5 ft wide x 5 ft high x 5 ft deep (1.5 x 1.5 x 1.5 m) (inside dimensions)

	Range	*Change Rate*
Altitude:	0 to 70,000 ft (21.4 km)	+10,000 ft/min (3 km/min) ascending −20,000 ft/min (6.1 km/min) descending

Airflows: two independently controlled: one for bay environment, one for ECS cooling air

Airflow Capabilities (each flow):

	Range	*Change Rate*
Mass Flow:	0 to 7.5 lb/min (3.4 kg/min)	±100 lb/min/min (±45.4 kg/min/min)
Temperature	−65° to +160°F (−54° to 71°C)	±120°F/min (±67°C/min)
Humidity	0.00001 to 0.04 Ws	±0.04 Ws/min

Vibration:

Simulator: one electromagnetic shaker
Frequency: 5 to 2,000 Hz
Modes: sinusoidal or random
Limits: 1 inch (2.5 cm) P-P amplitude, 17,500 lb force (7950 kg force)

*Humidity control is for ECS cooling air only

TABLE XII. GOVERNMENT CERT FACILITIES (Continued)

b) Central Inertial Guidance Test Facilities, Holloman AFB

		CHAMBER	CHAMBER
1. Chamber Dimensions		4'×4'×4'	8'×8'×11'
2. Test Specimen	Max. Dia. Max. Wt.		
3. Simulated Environments			
a. Temperature	Range °F	-100 + 300	-100 + 200
	Rate of Chg. °F/min	13.5	1
b. Vibration	Random lbf-Hz	9000 # 3-5000	17,000 # 3-3000
	Sinusoidal lbf-Hz	9000 # 3-5000	17,000 # 3-3000
	No. Axis & Orient.	1	1
	Max. Specimen Wt		
c. Altitude	Range ft	100,000	200,000
	Rate of Climb ft/min	7,000	35,000
	Rate of Descent ft/min	7,000	35,000
d. Humidity	Range % RH	30-98*	30-95
	Rate of Change % RH/min		
e. Cooling Air	Capacity lb/min	4**	
	Rate of Change lb/min/min		
	Range °F	-40 to 158	
	Rate °F/min	13.5	
	% RH - Range	30-95	
	% RH/min	6.5	
4. What is your ability to simulate mission profiles? Simulates mission profiles with HP Digital Control System			
5. What environments can be simultaneously and dynamically controlled? a, b, c, d, e			

*4°C and above

**Available after 1 January 1982

TABLE XII. GOVERNMENT CERT FACILITIES (Continued)

c) CERT Facilities at the Pacific Missile Test Center (Navy)

T-4827

	FACILITY[a]						ENVIRONMENTS				PROGRAM & STATUS		
	CHAMBER TYPE & DIMENSIONS	ACOUSTIC POWER (KW)	NUMBER OF SHAKERS & CAPACITY	REFRIC (H.P.)	HEAT (KW)	FAN (HP)	SKIN TEMP. EXTREMES (OF)	RANGE OF ACOUSTIC LEVEL (dB)	MAX SHAKER VIB (g's)	OTHER	PROGRAM NAME	NUMBER OF TEST ITEMS	ACCUMULATED TEST TIME CALENDAR PERIOD
1	Temperature/ Altitude/ Humidity/ 7'×7'×18'		2 ea.[b] 10K#	150	170	10	-45 +135		5.0	Altitude	PHOENIX AIM-54	1	6,000 hrs. 1974-1981
2	Acoustic[c] 6'×8'×7'	4	1 ea. 3K#					147	1.5		SPARROW AIM-7E	2	8,000 hrs 1972-1981
3	Acoustic 13'×16'×10'	20	3 ea. 10K#	90	54	10 2	-35 +160	145	0.4		SPARROW AIM-7F/M	6	10,000 hrs 1975 -
4	Acoustic[d] 13'×16'×10'	10	3 ea. 20K#	30	20	2	-20 +170	126-151	4.0	Landing Shock	SIDEWINDER AIM-9	6	35,000 hrs. 1978 -
		20		LN_2	30	3	-20 +150	146-154			AIS Pod P3 & P4	4	2,000 hrs 1976-1977
5	Acoustic 13'×16'×10'	10	2 ea. 5K#	100	36	7.5	-12 +160	126-150	2.0		HARM AGM-83	2	400 hrs. 1981 -
		10		10	10	3	-20 +100	140-143			HARPOON AGM-84	1	3,200 hrs 1978-1980
6	Acoustic[e] 13'×16'×10'	50		50	40	7.5	-20 +170 (est.)	130-157 (est.)			PHOENIX AIM-54		1981 -
7	Acoustic 16'×18'×12'	10		10	10	3	-20 +100	144-147		Ordinance Certified	HARPOON AGM-84	1	2,100 hrs. 1980 -
8	Acoustic 16'×18'×12'	40		90	54	10	-20 +170 (est.)	130-157 (est.)		Ordinance Certified	PHOENIX AIM-54	4	1981 -

a The most recent description of the facilities and test results is provided by D.B. Meeker and W.D. Everett, "U.S. Navy Experience on the Effects of Carrier Aircraft Environment on Guided Missiles," AGARD conference proceedings Number CP270, May 1979.

b The vibration technique in this facility is described by C.V. Ryden, "Dual Shaker Vibration Facility," Shock and Vibration Bulletin, Number 46, Part 3, (1976), pp. 27-53.

c The effectiveness of this acoustic facility is described by J.C. Calkins and A.G. Piersol, "Simulation of the SPARROW Vibration Environment," SAE Booklet, Number 730939, (1973).

d The combined thermo-acoustic facility was first described by W.D. Everett, "Thermo-Acoustic Simulation of Captive Flight Environment," Shock and Vibration Bulletin, Number 46, Part 3 (1976) pp. 103-111.

e The rationale for the transition to this facility by A.M. Spandrio and M.E. Burke, "Acoustics or Shakers for Simulation of Captive Flight Vibration," Shock and Vibration Bulletin, Number 48, Part 4, (1978), pp. 5-13.

TABLE XIII. INDUSTRY CERT FACILITIES

T-4782

COMPANY		CHAMBER DIMENSIONS	TEST SPEC SIZE & WT		TEMPERATURE	VIBRATION	ALTITUDE	HUMIDITY	COOLING AIR
Applied Technology	2 ea	54"×54"×36"	60 ft^3	500#	-100+350	300# 20-60 Hz	-	-	mech refrig
	2 ea	62 ft^3	24"	500#	-100+350	10g 20-200 Hz	-	-	mech refrig
Thermatron		27 ft^3	12 ft^1	350#	-100+350	-	100,000	-	-
Tenney		27 ft^3	12 ft^3	350#	-100+350	-	100,000	-	-
Tenney		20 ft^3	8 ft^3	140#	-100+240	-	-	-	-
Thermatron		64 ft^3	30" dia	500#	-100+350	-	120,000	20-98	-
Bell Aerospace		8'×8'×10'			-80+300	20,000# 200 Hz	80.000	0-100	To-80°F
Continental Testing					-300+480	4200# 2000Hz 6000# 3000Hz	>100,000	0-100	300-400#/min -100°F+167°F
Cubic Corporation		62 ft^3	36"	100#	-163+350	6000#	-	-	-
		32 ft^3	30"	100#	-163+350	5000#	-	-	10#/min 20-200°F
Eaton Ail Division		9 ft^3	3.6 ft^3	500#	-100+300	-	-	20-100	-
Blue M									
Thermatron		110 ft^3	44 ft^3	700#	-100+300	9,500 R 13,500 S	-	-	200 ft^3/min -85+300
Thermatron		62 ft^3	25 ft^3	500#	-100+300	1000 S	-	-	-
Tenney		36 ft^3	14 ft^3	1000#	-100+300	-	80,000	20-100	-
Tenney		8 ft^3	3.2 ft^3	1000#	-100+300	-	-	20-100	-
Thermatron		32 ft^3	13 ft^3	1000#	-100+300	500# S	-	-	-
Thermatron		62 ft^3	24 ft^3	500#	-100+300	1000# S	-	-	
Conrad		1000 ft^3	400 ft^3	1000#	-100+300	-	75,000	20-100	

TABLE XIII. INDUSTRY CERT FACILITIES (Continued)

T-4783

COMPANY	CHAMBER DIMENSIONS	TEST SPEC SIZE & WT		TEMPERATURE	VIBRATION	ALTITUDE	HUMIDITY	COOLING AIR
Grumman Aerospace	4'×4'×4'	2'×2'×2'	250#	-100+350	860/2000 R 1200/2000 S	80,000	20-95	Aux Blower
	4'×4'×4'	2'×2'×2'	250#	-100+350	5000/100 S	80,000	20-95	Aux Blower
	4'×4'×4'	2'×2'×2'	250#	-100+350	-	-	20-95	Aux Blower
	4'×4'×4'	2'×2'×2'	250#	-100+350	-	80,000	20-95	
	8'×8'×12'	3'×6'×4'	1500#	-80+300	-	70,000	20-95	
Hughes Aircraft Co.	7'×8'×18'	6'	1500#	-110+400	5-60 Hz S	150,000	20-1000	25 @ S/L 9 @ 70k ft
	7'×8'×18'	6'		-100+250	5000/2000 R 7000/2000 S	70,000	-	25 @ S/L 9 @ 70k ft
	6'×6'×6'	4'	500#	-100+200	5-60 Hz S	-	-	3#/min
Kollsman Instrument Co.	20×20×20			-100+45	-	100,000	-	
	24×24×30			-100+350	-	100,000	-	
	40×40×36		500#	-100+260	20-60 Hz 5g	-	-	
	40×36×40			-100+450	5-60 Hz 3g	-	-	
	48×48×48			-100+350	-	-	-	
	30×30×30			-100+212	-	-	-	
	40×36×26			1.4+199	-		20-98	
Sine Vib					1500/5-3000 S 3 Axis			
Litton Guidance & Control	40×40×36	30"	600#	-100+250	8000# R 9000# S	90,000	20-99	1-8#/min -65+200°F
McDonnel Douglas Corp.	48×48×72			-100+400	14,000# R 17,500# S	80,000	20-95	
Norden	6'×9'×13'			-100+360	6000# R 4500# S	-	50-95	30#/min -65°-131°F
Singer 14 ea	62 ft³ (AGREE TYPE - CERT PLANNED IOC 1981)							

TABLE XIII. INDUSTRY CERT FACILITIES (Continued)

T-4784

COMPANY	CHAMBER DIMENSIONS	TEST SPEC SIZE & WT		TEMPERATURE	VIBRATION	ALTITUDE	HUMIDITY	COOLING AIR
Sperry	12'×18'×14'	3'	1000#	-90+350	16,000/2000 R 21,500/2000 S	90,000	0-95	
	6'×4'×4'	3'	1000#	-90+200	16,000/2000 R 21,500/2000 S	-	-	
	3'×3'×4'	2'	150#	-90+200	2500/2000 R 3500/2000 S	-	-	
	2½'×2½'×5'	1½'	30#	-90+200	900/2000 R 1200/2000 S	-	-	
	6'×4½'×5'		500#	-99+347	4000/2000 R 5600/2000 S	-	781C	
	10'×16'×9'		2000#	-99+351	-	-	781C	
	6'×4½'×4'		1000#	-65+257	5-60 Hz S	-	-	
	6'×6'×6'		1000#	-100+300	1500/2000 S 3 Axis	-	0-98	
	2'×2'×2'		150#	-100+300	30 Hz 3 Axis	-	-	
Zeta Laboratories	12"×12"×12"	9"	50#	-100+300	850# R 1200# S	-	0-98	

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APPLICATION OF CERT FOR EQUIPMENT INTENDED FOR MULTIPLE AIRCRAFT APPLICATIONS

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FOREWORD

The use of Combined Environment Reliability Testing is discussed as a tool for achieving product reliability. The selection of the appropriate test strategy to fulfill multiple test objectives is discussed as well as how the selection is affected when dealing with equipments destined for multiple aircraft applications.

1. BACKGROUND

During the last decade or so, a number of efforts have been undertaken to improve the methods for testing and evaluating avionics. Some of Col. Ben Swett's efforts and the report to the Air Force Studies Board on Reliability in Aeronautical Avionics Equipment in 1975, for example, were quite well publicized. These efforts were generally critical of the lack of realism in the reliability testing process for avionics equipment.

At about the same time, there was a growing awareness that, if the ratio of dollars for O&S (Operations and Support) to dollars for new equipment continued to increase, almost all available funds would be consumed by O&S before too many years elapsed. At that point, resources would be unavailable for investment in new equipment required to meet changing threats. Thus, the PRAM (Productivity, Reliability, Availability and Maintainability) Program Office was chartered in 1975 to mount a concerted and focused effort on developeing methods to reduce the Air Force's overall O&S burden.

Just as PRAM was being formed, the Air Force Flight Dynamics Laboratory (AFFDL) was finishing an experimental CERT (Combined Environment Reliability Testing) evaluation of the F-111 Terrain Following Radar and concluded that the laboratory results correlated well enough with field experience to merit further investigation of CERT. These activities provided impetus to incorporating some form of CERT within the version of MIL-STD-781C which was then in a coordination cycle. Thus, the scene was set for PRAM, along with AFFDL and Aeronautical System Division's Deputy for Engineering (ASD/EN), to embark on an evaluation of the technical merit and cost-effectiveness of CERT. On the one hand was the possibility of duplicating and then fixing every possible failure that might be encountered in the field being offset by potentially very large expenditures for facilitization, testing, and incorporating fixes.

As is well known and documented, the CERT evaluation has been in progress since then and should be concluded this year. During this period, though, it became evident that other variables, besides test conditions and field reliability, were driving O&S costs. Another major influence toward increasing O&S

costs was the proliferation of avionics, along with the increasingly expensive, dedicated and often peculiar support systems required to keep the avionics operational. To address the proliferation problems and promote standardization, the Air Force established the Deputy for Avionics Control in 1978.

A major function of the Deputy for Avionics Control is to serve as secretariat for the Air Force's annual Armament and Avionics Planning Conference and to produce avionics planning guidance for Headquarters USAF as a result of the conference. The conference consists of four standing panels: Availability, Computer Resources, Combat Effectiveness, and Standardization. The following list represents a sample of the avionics that the Standardization Panel has endorsed as future "standards" to be installed in "multiple-host" aircraft:

a. CARA - Combined Altitude Radar Altimeter
b. MRR - Multi-Role Radar
c. CADC - Central Air Data Computer
d. ARC-164 Replacement
e. Standard Crash Data Recorder.

Obviously, changes can and probably will occur. The point is that more and more standard avionics are programmed and destined for our operational inventories.

Some recent acquisition strategies, such as concurrency (entering production before completing Full-Scale Engineering Development) have served to highlight the role, importance and character of developmental testing as a tool in achieving product reliability. Since concurrency tends to disallow programmatic windows for formal reliability qualification tests, TAF (Test-Analyze-Fix) is emerging as one of the more important tools for Full-Scale Engineering Development application. And, as CERT is maturing, it is becoming an integral element of the TAF process, in addition to its utility during other phases of a reliability program. These considerations are embodied in the recent DoD Directive 5000.40 which requires that:

"... performance, reliability and environmental stress testing shall be combined, and types of environmental stress will be combined insofar as practical..."

with an emphasis on reliability and maintainability growth.

In view of increasing standardization and the integration of CERT and TAF techniques as influenced by acquisition strategies such as concurrency, this paper is intended to stimulate workshop discussion on this issue:

For systems destined for multiple-host applications, how are CERT tests most effectively structured?

Some concepts employed in the past and other ideas are provided in the subsequent sections to establish the discussion baseline.

2. CURRENT REQUIREMENTS

A wealth of information on existing testing requirements can be found in the various directives, regulations and Military Standards. Both MIL-STD-781C and MIL-STD-785B describe the need for Integrated Testing, with 785B language closely reflecting the wording of DoD Directive 5000.40.

MIL-STD-781C lists the following tests in its breakout discussion of integrated testing:

a. Reliability development tests
b. Environmental development tests
c. Environmental qualification tests
d. Reliability qualification tests
e. Reliability acceptance tests
f. Burn-in and screening tests.

The new MIL-STD-785B lists the same tests and characterizes them in terms of reliability engineering tests and reliability accounting tests. In general, the

integrated test programs progress from environmental testing (MIL-STD-810) to reliability development growth testing and then to the "accounting" reliability qualification and production reliability acceptance tests.

MIL-STD-781C contains ample guidance with respect to developing testing environments as a function of composite mission profiles. Most past testing has probably been accomplished using the composite environmental profiles relevant to a single weapon system for which the avionics has been targeted.

Now, if the implications of standardization are considered - - a composite mission profile takes on a different meaning for, in their case, the composite should account for transport, bomber and fighter missions, as contrasted with a composite within one MDS (Mission Design Series) aircraft. Again, DoD Directive 5000.40 stipulates that "Test conditions and procedures shall be operationally realistic..." In summary, the policy as well as the technical guidance are in place. The remaining challenge is in developing a conceptual framework for structuring tests that can minimize life-cycle cost for standard avionics across multiple-host platforms.

3. EXISTING OPTIONS FOR MEETING REQUIREMENTS

A major problem which confronts government organizations responsible for reliability programs is the selection of tests which can aid in attaining program reliability requirements. Schedule and funding constraints mandate a cost-effective selection. The reliability test program should serve three objectives:

a. Disclose deficiencies in designs, material and workmanship.

b. Provide data to support manpower and logistics support cost estimates.

c. Determine compliance with quantitative reliability requirements.

Several options are discussed in the following sections.

3.1 Serial Testing

Serial testing, in the context of this report, is comprised of a series of tests which are structured to meet the reliability test objectives stated above. Several types of testing can be used complementarily in order to meet stated objectives. A frequent example is that of MIL-STD-810 type environmental tests followed by Reliability Qualification Testing (RQT). The remainder of this section addresses these and other types of testing.

Environmental tests are specifically designed to disclose weak parts and workmanship defects for correction. These tests should be applied to parts, components, subassemblies, assemblies or equipment to remove defects which would otherwise cause failures during early field service. The test conditions and procedures should be designed to stimulate failures typical of field service, rather than provide precise simulation of operational life profile. Environmental stress types may be applied in series rather than in combination and should be tailored for the level of the assembly at which they are most cost-effective.

Engineering Development testing using CERT (Combined Environment Reliability Testing) is a strategy that can result in early identification and correction of design deficiencies. If CERT were used, for example, in a planned, pre-qualification, test-analyze-fix (TAF) process, real reliability growth is possible. A key point here, however, regardless of test methodology, is that appropriate and selective corrective action, taken to preclude operational repetition of test-induced incidents, is the mechanism that actually improves reliability. If employed, it is imperative that TAF testing for the sake of reliability growth be implemented early in Engineering Development because the early iterative design process is more fluid, more accommodating of design changes, and less subject to formal configuration control. The later that TAF using CERT is initiated, the greater are the risks of postponing required corrective actions and incurring later retrofit problems.

Reliability Qualification Testing is intended to provide the government some assurance that minimum acceptable reliability requirements have been met before items are committed to production. RQT should reflect operational conditions and permit estimates of demonstrated reliability. The statistical test plan must pre-define criteria of compliance which limit the probability that true reliability of the item is less than the minimum acceptable reliability requirement. RQT is required for items that are newly designed, for items that have undergone major modifications, and for items that have not met their allocated reliability requirements.

In summary, with schedules and resources permitting, an appropriate sequence of reliability testing would be: (1) environmental tests to remove defects in the test items, (2) Engineering Development tests, perhaps employing CERT methods in a TAF process, to disclose and correct design deficiencies and defects, and (3) RQT, again using CERT methods, to provide reasonable assurances of having met minimum acceptable reliability requirements.

3.2 Simultaneous Testing

As discussed in the above section, three types of reliability tests have been identified which together serve the reliability test objectives. However, schedules are not always adequate to allow for series testing in which information learned from one test series may be passed to the next test series. For this reason, the government utilizes simultaneous testing, i. e., combining two or more test objectives at the same time. In a test program constrained by schedule or budget, it may be desirable to incorporate selected qualification test levels in a combined environmental test. The incorporation of qualification test levels in the test profile may involve exposing those units under test to levels of stress which exceed those under which they are designed to operate; however, evaluation of the equipment can be enhanced by the accumulation of data relating to:

a. Equipment environmental limits
b. Early discovery of latent failure modes
c. Marginality of design.

Sensitivity of equipment designs to severe environments should become readily apparent. Failure modes that would not ordinarily be observed for thousands of test hours or several months in the field may be "shaken out" early. In a competitive procurement, the relative sensitivities of different contractors' equipments to stress levels above the design limits may be of importance to the government as a proposed evaluation criterion. The greatest benefit to the government, however, is the potential for design improvements which are proposed or implemented by the contractor on data obtained while exposing the equipment to combined environmental stresses.

3.3 Combined Environment Reliability Test Objectives

As alluded to in the previous section, it is often necessary to blend test objectives if they are to be met within schedule and budget constraints. While it may be impossible to meet all test objectives through a single test series, multiple objectives across test series can be accommodated by applying differing versions of CERT. The combined simulated environments, characteristic of CERT as used in an RQT, for example, can be enhanced or intensified and used as a stress screen to stimulate additional failures or incidents that become corrective action candidates. This procedure, when integrated with dedicated failure analysis and corrective action systems, is referred to as the TAF methodology.

CERT is a powerful test that can be utilized for various purposes. By exposing equipment to typical (simulated) or worst-case (stimulative) flight environments in the laboratory, the following objectives of CERT may be fulfilled:

a. Failure mode isolation
b. Equipment qualification
c. Accelerated testing
d. Reliability prediction
e. Reliability growth.

Not all of these objectives, however, can be accomplished in a single, combined environment test. The realization of each depends on the characteristics of the selected environment profiles and on the specific test methodology employed. Besides the realization of failure mode isolation or equipment qualification which have previously been discussed, the objectives which support the three reliability test program types listed earlier, are discussed in the following paragraphs.

Accelerated Testing - The greater the time and the amount of data accumulated, the greater the confidence that can be placed in the results from the tests, especially the reliability estimates. With combined environment testing using acceleration techniques, it is possible to accumulate a large amount of simulated flight data in a relatively short period of time. There are two important types of test acceleration:

a. Time acceleration
b. Environment acceleration.

In a time-accelerated test, the simulated environment profiles deemphasize the benign mission phases that are assumed not to generate many failures. The benign phases include extended cruise and ground time. Accordingly, most of the test cycle is devoted to the more stringent environments associated with takeoff, climbout and altitude changes. If the assumption is valid that few failures are induced by the benign mission phases, then the ratio between the times of the average actual mission and the laboratory mission is a valid test acceleration factor (k-factor) applied to laboratory MTBF in order to estimate field MTBF. This factor is used to convert test time to equivalent flight time for field reliability prediction. The k-factor is clearly laboratory test-mission dependent.

In an environmentally-accelerated test, the environment levels employed are more severe than those associated with a typical mission profile (or with the design limits of the equipment). Accelerated environments are used to stimulate and detect equipment failure modes that would not be exhibited under expected

flight conditions or would not be observed until the equipment was exposed to normal conditions for longer periods of time associated with equipment wear-out modes. It is difficult, for test environments accelerated beyond normal flight levels, to derive a test acceleration factor for converting test results to equivalent flight results.

Reliability Estimation - In a competitive procurement, such as the OMEGA Program 2041 in which equipment life-cycle cost was a primary evaluation criterion, the life-cycle cost of competing contractor's equipment may exhibit different sensitivities to variations in equipment MTBF.* For these procurements, consistent reliability estimation is an important issue and combined environment testing may be a primary source for such reliability data.

The combined environment test methodology was developed because of the inability of traditional test methods to adequately predict the nature of field behavior for avionics equipment prior to deployment. The major problems with the MIL-STD-781B test methodology are:

a. Absence of a realistic field environment in the laboratory.
b. Lack of acceptable levels of correlation between laboratory and field reliability.

The use of the dynamic combination of temperature, pressure, humidity and vibration in the laboratory test flight pofile is a major development in overcoming the first obstacle.

In addressing the laboratory/field reliability correlation problem, it is important to distinguish between two types of combined environmental tests:

a. Combined environmental reliability test.
b. Combined environmental stress test.

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* It is possible, given one set of MTBFs for the various competing contractors, that the ranking by life-cycle cost would change if the MTBF for each contractor were doubled or changed by a similar factor.

If the test objective is to estimate the equipment's field reliability, then the environmental levels in the laboratory should be compatible with those in the field to simulate failure modes. If the objective of the test is to identify equipment environment sensitivity and tolerance, then accelerated environments should be employed to stimulate failure modes.

Reliability Growth - There are two types of reliability related issues:

a. Reliability estimation
b. Reliability growth.

As discussed above, valid reliability prediction requires the selection of a representative environment profile and the derivation of an appropriate correlation factor to relate laboratory test experience to expected operational experience. Testing to achieve reliability growth may not be compatible with testing to predict field reliability. For example, in a program constrained by schedule, "locally optimum" reliability growth may require stressing the equipment to its limits, thereby uncovering failure modes which result in early design improvements. Such an approach may reduce confidence in field reliability estimates due to problems associated with:

a. Deriving a k-factor for accelerated environments
b. Allocating test data among different design configurations of the same equipment.

Therefore, during the planning stages of a test program, the engineer must be prepared to:

a. Evaluate cost-effectiveness tradeoffs between reliability growth and reliability prediction.

b. Develop guidelines for matching environment stress levels with the available program test time.

3.4 Test Application

The government may wish to apply any or all of the above referenced reliability tests on selected weapons systems. When the avionics system is being procured or tested for a single-aircraft application, the problem of identifying the range and duration of environments within which the equipment is expected to operate is simpler than the case of a multiple-host application. After determining the environmental conditions representative of those encountered by the equipment aboard the host aircraft during a typical mission, the selected environment profile should cover the major operating areas of the host aircraft flight profiles. Representative profiles can be developed by utilizing all available data from flight logs and historical records.

The test objectives for avionics destined for multiple applications should remain relatively unchanged. However, the task of selecting the appropriate test environment for a multiple-host application can take on added dimensions in terms of selecting appropriate test conditions that will minimize operating and support (O&S) costs. It is not entirely clear that testing a piece of avionics equipment under the most severe environmental conditions that it might encounter on one of its host aircraft would be most effective. In the case of a homogeneous population of avionics equipment, it is readily conceivable that equipment currently used in a fighter environment may later be installed and operated in bomber or turboprop environments.

Assuming some sort of limits on test time and resources, the temperature (also vibration, humidity, etc.) profiles should be chosen so as to result in highest life-cycle payoffs. It might be judicious to test to environments that are not necessarily the most severe, but that will be most common in order to effect the maximum reduction of O&S costs. The concept of a composite profile, i.e., across applications, for each environment also merits analysis. Figure 1 which can be interpreted as a discrete distribution of temperatures, actually depicts the temperature profiles from MIL-STD-781C for jet and turboprop aircraft. Temperature has been plotted for 10 aircraft conditions across 14 mission phases. Each aircraft condition and mission phase is specified in Table I. As can be seen in Figure 1, temperature for the first 5 aircraft

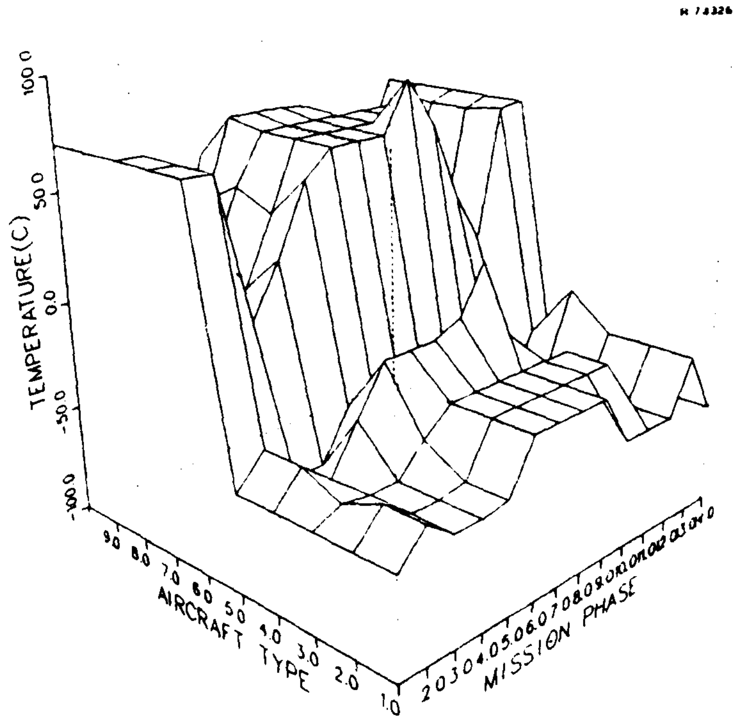

Figure 1. Temperature Ranges Derived from MIL-STD-781

TABLE I. AIRCRAFT TYPE AND MISSION PHASE

INDEX	MISSION PHASE	AIRCRAFT TYPE
1	Ground Runup	Fighter Air-Conditioned Cold
2	Takeoff	Bomber Air-Conditioned Cold
3	Climb	Turboprop Cold
4	Cruise High	Fighter RAM Cold
5	Cruise Medium	Bomber RAM Cold
6	Cruise Low	Fighter Air-Conditioned Hot
7	Combat Low	Bomber Air-Conditioned Hot
8	Combat Medium Low	Turboprop Hot
9	Combat Medium High (L)	Fighter RAM Hot
10	Combat Medium High (H)	Bomber RAM Hot
11	Combat High	Not Used
12	Start Descent	Not Used
13	End Descent	Not Used
14	Land	Not Used

types (which are operating in a cold environment) range from -54°C to -26°C for the bomber/air-conditioned (aircraft type 2) to -55°C to 19°C for the fighter/RAM air cooled (aircraft type 4). Likewise, temperature for the last 5 aircraft types (which are operating in a hot environment) range from -28°C to 71°C for the bomber/RAM air cooled (aircraft type 10) to 10°C to 93°C for the fighter/air-conditioned (aircraft type 6). Simple comparison shows that the fighter/RAM air cooled covers a wider temperature region for the cold environment while the bomber/RAM air cooled provides a wider temperature region for the hot environment with the fighter/air-conditioned category containing the highest peak temperature.

Thus, the temperature environment from MIL-STD-781C is most severe for fighters, a condition probably magnified when the time dimension is factored in. A typical fighter mission may last approximately 1.5 hours while a bomber mission may exceed 10 hours. When one considers that the temperature ranges for the fighter aircraft must be covered more quickly than for a bomber aircraft, it is apparent that the rate of change in temperature is more rapid and probably more stressful in the fighter.

If the solution to testing is to select the worst environment, then the fighter environment should be selected. However, suppose that the equipment selected is to be installed in a limited number of fighters, and in many bomber and cargo aircraft. If the fighter environment is used, what should be done with failure models peculiar to the extremes of the hot temperature profile (i.e., 93°C) which will not be experienced by the bomber and cargo aircraft? Even more important, what is the proper disposition of failures resulting from rapid temperature cycling in the fighter environment, but which may never appear in bomber and cargo application because of their slower changes in temperature and longer periods of relative thermal stability. <u>With increasing emphasis on reducing avionics proliferation and promoting standardization, tools for supporting such analyses must be developed.</u>

4. REQUIREMENTS -- ANOTHER PERSPECTIVE

As described earlier, policy and technical guidance for the requirement to structure and conduct integrated test programs already exist. In today's environment of greater need for standardization because of increasing operational and support costs, it is perhaps appropriate to consider the overriding requirement of minimizing life-cycle costs as a function of applying CERT to standard avionics during engineering development.

4.1 "Most Representative" Conditions

While the task of structuring a CERT test is challenging enough for the case of a single-host aircraft or platform, it can take on additional dimensions if:

a. The avionics will be hosted on multiple platforms
b. Resources are available for only one developmental test program
c. A primary consideration is to minimize life-cycle costs.

For example, consider the familiar curves shown in Figure 2. If it is assumed that the [illegible] curve represents the improvements in reliability that are ideally possible for given R&D expenditures, then departures from the ideal, as shown, will result in a new, higher total cost curve, TC'. This situation occurs when resources are invested into an R&D test program without an appreciable increase in aggregate (i.e., across all applications) avionics system reliability. The least desirable condition occurs when no aggregate reliability improvement is realized for a given R&D expenditure, and the total cost curve merely shifts vertically toward TC'. Such an outcome could result from:

a. Conducting excessive tests
b. Conducting the wrong tests
c. Conducting tests that are "right" for only a very small subpopulation, but applying the indicated fixes to all units.

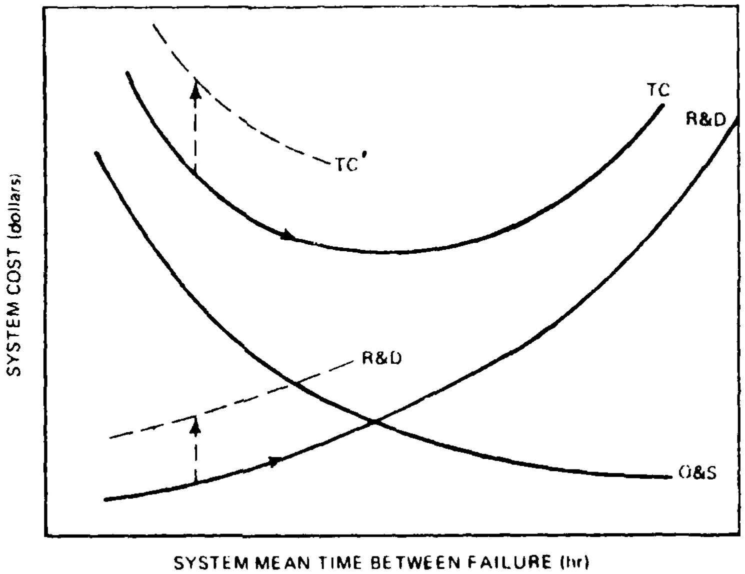

Figure 2. Life-Cycle Costs

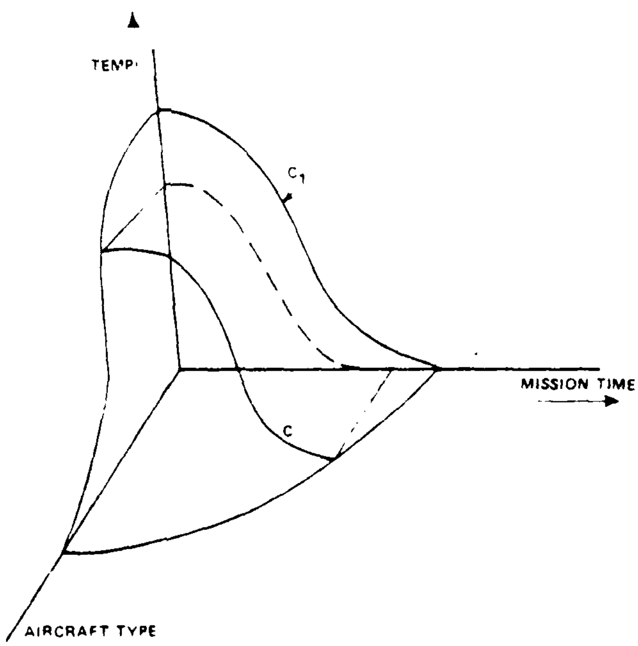

Figure 3. Simplified Temperature Distribution

If the CERT requirement is derived from a higher-level requirement to minimize life-cycle or total cost for a standard avionics system, then complying with DoD Directive 5000.40 with respect to operational realism in test procedures and conditions will require some analysis of the avionics system population.

The CERT test objective for standard avionics should remain relatively unchanged -- to achieve reliability growth or reliability qualification under conditions that are most representative of expected operational conditions. It seems that one of the first tasks would be to assess the homogeneity of the avionics equipment population -- i.e., to what extent would partitions be imposed on, say, a standardized TACAN? Would fighter TACANs always remain fighter TACANs, or could such items be re-cycled back to tankers or helicopters? Whether or not the population is partitioned, how much support equipment would be required for each host platform type?

Consider the distribution and time rates of change of temperatures to which a standard black box might be exposed. For discussion purposes, part of the three-dimensional projection of that distribution might appear as shown simplistically in Figure 3. Curve C_1 might represent the CERT conditions for a given platform. But if Curve C represents the optimal solution for all platforms, then testing to Curve C_1 conditions would exceed the optimal CERT conditions represented by the dashed projection onto the plane of C_1. Such testing could then result in fixes that are costly and superfluous for most of a standard avionics population.

As stated earlier, the concept of composite (across platforms) mission profiles deserves analysis. Equally deserving of analysis are the potential consequences of testing at environmental extremes to be encountered only by sub-populations -- it may be very cost ineffective, for example, to implement corrective action on every unit, or even on any unit, based on results from a CERT test that imposes (severe) conditions to be seen in only a small percentage of applications. On the other hand, for "most representative" or perfectly selected composite profiles employed in a CERT TAF test, every incident occuring

during test should be regarded as representative of expected field incidents and thus a candidate for population corrective action.

4.2 Effects of Worst Case Environments

As outlined in Section 3.4, the selection of the worst case environment for the test profile may lead to identification of failure modes which may not occur in the most common of installations. For example, if a standard piece of avionics is destined for fighter and bomber applications and the population will be homogeneous so that units can be installed in any application, spares may be reduced because of pooling of resources at the depot and perhaps even at collocated bases. Therefore, the population is maintained as homogeneous in order to realize O&S cost reduction through lower spares costs. However, if the fighter environment, which is more severe than that of the bomber, is selected and makes up only a small percentage of the total installation, it is possible that failure modes which are unique to the fighter may be identified and corrected without causing any substantial improvement in bomber O&S costs that result from the majority of the avionics installations. This could lead to increased aggregate life-cylce cost since the cost to incorporate the design corrections by the use of Engineering Change Proposals (ECPs) may not be recouped through O&S cost reduction over the life of the system.

Another possible result of worst case environment testing is the additional test time in a cycle which may be necessary in order to allow the test chamber enough time to reach the desired temperature. If an objective of the test program is to improve reliability in order to reduce O&S costs, then it is desirable to run as many full mission cycles as possible in order to gain maximum data over the expected environment. However, by requiring the test chamber to reach extreme environments the test cycle time must be lengthened to allow for this. The lengthening of the test cycle reduces the number of cycles that may be run in a specified period of time (i.e., day, week, month, etc.). In a program constrained by schedule and budget, this results in fewer cycles and therefore loss of mission data in order to acquire data on a mission phase which may not be germane to the major portion of the avionics environment.

Where an equipment is considered mission critical, the above arguments against worst case environment testing must be tempered by the role the equipment plays in the successful completion of the mission and where in the mission (before or after the need) the extreme environment occurs. If the equipment is required for the successful completion of the mission and must be able to operate through the worst case environment, then the equipment must be designed or improved to allow for this. However, where the equipment is considered critical on a small percentage of the total installations or where the ability to operate successfully through the worst case environment is critical for a small number of installations, then testing to worst case environments may be an expensive method of improving mission completion success probability (MCSP). Tradeoff studies may be necessary to determine whether the cost to improve MCSP for a small number of applications and marginal reduction in O&S costs justifies the price of required ECPs.

An attractive solution to the above problem might be to partition the equipment population so that design corrections may be made to only those units which will support the fighter application. This will result in increased life-cycle cost because of the loss of pooling of resources in terms of spares. It may also impact other logistics aspects such as support equipment if the support equipment must be altered in order to verify and repair failure modes which occur under special environmental conditions or stresses.

As can be seen from the above discussion, the improvement or measurement of reliability is not for its own purpose but rather as a means to an end, such as reduction of O&S costs or improvement in MCSP. Therefore, <u>when planning a reliability test for a multiple aircraft application, the test planner must be aware of the contribution of the environmental conditions across applications before deciding to focus undue attention on it in the test</u>. Without considering the entire situation, design changes may be incorporated which will not alter the O&S cost curve sufficently to justify their expense.

5. IMPLICATIONS FOR FUTURE CERT APPLICATIONS

In this section, the concept of minimizing aggregate cost is reiterated, followed by an example framework that could be useful in selecting the appropriate test strategy.

5.1 Aggregate Cost

In today's environment of rising O&S cost and more standardization of avionics, a methodology must be developed for specifying CERT testing environments such that life-cycle costs will be minimized. In the context of this paper, life-cycle cost pertains to the aggregate life-cycle costs across all platforms targeted to host the standard avionics. An implicit assumption is that information such as target platforms, operational environments, missions, required avionics quantities, etc., is available. Some of that data is becoming available through the Deputy for Avionics Control's data collection and avionics planning activities. With regard to the testing itself, it is to be expected that CERT profiles optimally derived to minimize aggregate cost across all host platforms may very well be technically sub-optimal when considered on a single-platform basis. To reiterate: if the testing profile results in actions to minimize aggregate costs for standard avionics, the profile is optimal.

5.2 Decision Aid

The selection of the proper test strategy has been discussed in several of the preceding sections. A preliminary decision flow has been outlined in Figure 4 and is discussed in the following paragraphs.

The first decision one may be faced with is whether the equipment is meant for single-host application or multiple-host applications. This decision will probably have already been made by a higher authority prior to the test planning effort. However, the issues raised in Section 4 should be kept in mind such as incorporating ECPs in order to reduce O&S costs or to improve MCSP for small percentages of the total inventory. Having made the decision concerning candidate applications, it is necessary to generate typical flight profiles that are

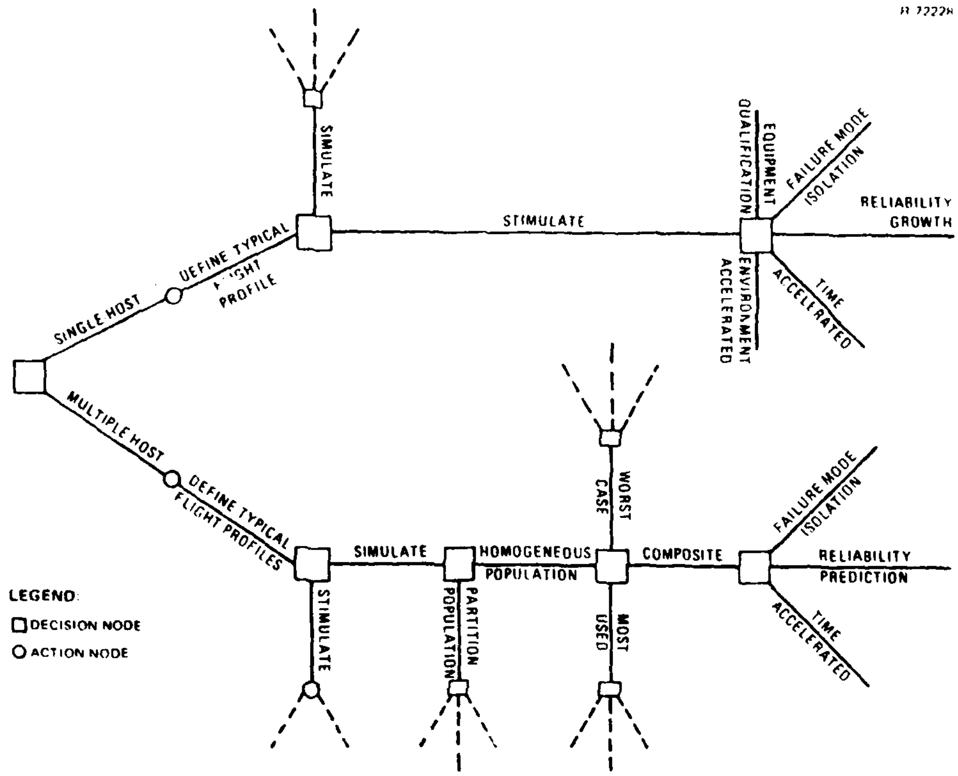

Figure 4. Test Planning Decision Tool

truly representative. This would include consultation with the using command, aircraft manufacturer, study of similar systems, and use of MIL-STD-781 guidelines.

The decision to simulate the flight environment or to test to a stimulative flight environment is largely based on the ultimate test objectives. If reliability measurement is the prime objective, then a simulated environment is recommended. This is because of the need to generate k-factors or other correlation techniques. Reliability measurements are extremely useful as a planning

tool to estimate logistic requirements and spares allocations. Additionally, it may be useful as a measurement in a warranty program or other form of equipment guarantee. However, if the ultimate objective is reliability improvement then a stimulative flight environment is recommended. A stimulative environment can accelerate the identification of failure modes which can lead to earlier design changes and greater O&S cost reduction by avoiding costly retrofit expenditures. The use of life-cycle cost estimating tools would be extremely useful in determining whether it is advisable to use simulated environments to estimate logistic costs (usually when the O&S cost curve is flat so that changes in reliability have little impact on O&S costs) or stimulative environments to improve reliability (usually when the cost curve is steep so that changes in reliability have a substantial impact on O&S costs).

In the case of the multiple-host application, the decision of whether the equipment is to be treated as a homogeneous population or as a partitioned set will probably have been made by a higher authority. However, the tradeoffs discussed in Section 4.2 should be addressed in order to assess the impact of ECPs necessary to perform the mission and its potential for marginal reductions in O&S costs.

Selecting among worst case, composite, and most-often-used flight environment is dependent on the decision to simulate or to stimulate and the composition of each environment in terms of percentage contribution across the inventory. Where the decision is to stimulate test incidents, the worst case baseline environment is usually selected. However, if there is a great disparity between applications,then the use of a composite environment might be more meaningful. If the decision is to simulate the environment, the use of the most-often-used flight profile might be selected in order to more accurately predict reliability for O&S cost estimation. If the worst case environment under the stimulated decision branch constitutes only a small percentage of the total inventory, then stimulating the environment from the most-often-used baseline may result in identifying and accelerating failure modes which have a greater impact on total system life-cycle cost. On the other hand, if the environments are close so that little difference exists between least severe and most severe flight environments, the worst case environment should be selected under the simulate condition so that identification of failure modes can be accelerated while gaining maximum O&S cost reduction through design improvement.

Ultimately, the test objective(s) as discussed in Section 3.3 should be selected. If reliability prediction is the prime goal then the use of simulated environments is recommended. However, if reliability growth, equipment qualification or accelerated environments are principal objectives then stimulative flight profiles are suggested. The use of laboratory equipment to simulate or to enhance flight environments makes it possible to generate a maximum amount of test time in short periods of time as compared to flight testing. Therefore, it is possible to acquire time acceleration of data regardless of the decision to simulate or to stimulate. Failure mode isolation is a major objective of reliability measurement or reliability growth and fits into either decision. The environmental profile can be closely monitored in the laboratory and the occurrence of equipment malfunction may be associated with the environmental conditions under which they occur.

6. SUMMARY

Combined Environment Reliability Testing (CERT) has been identified as a useful tool in achieving product reliability. The recent DoD Directive 5000.40 requires that:

> "... performance, reliability and environmentsal stress testing shall be combined, and types of environmental stress will be combined insofar as practical..."

Therefore, the requirements exist in terms of combined environment testing, but the question remains on how best or proceed.

The decision to simulate operational conditions or to stimulate additional test incidents by enhanced environments is based largely on the primary test objective. If the main test objective is to predict field reliability then the use of a simulated environment is recommended. However, if the main test objective is to encourage maximum reliability growth then the use of a stimulative environment is recommended.

Before the decision to simulate the operational environment or to stimulate additional test incidents is made, a typical baseline flight profile should be

generated so that test environments may be selected in order to achieve one or more of the test objectives. In the case of equipment destined for multiple-host application, the selection of the appropriate baseline flight profile is complicated by the need to cover all of the major operating areas of several different aircraft classes.

The appropriate test strategy should be determined through an analysis of effects on reducing operating and support (O&S) costs. Guidelines have been outlined in this report with respect to tradeoffs between potential O&S cost savings and the cost to incorporate design changes. The need exists to develop decision tools to aid the program manager or engineer in selecting the correct test strategy and in establishing the test environments appropriate to the class of equipment and the specified applications.

SECTION IV - WORKING GROUP SESSIONS

INTRODUCTION

This section presents the detailed response to the issues which were deliberated by the four working groups at the Combined Environment Reliability Test (CERT) Workshop. The overall purpose of the workshop was to develop recommendations concerning the use of CERT in the acquisition process. To achieve this end, the four working groups addressed several issues pertaining to the specific topics of CERT Management/Cost Effectiveness, Technical Applications, Facilities Capabilities, and MIL-STD-781 and MIL-STD-810. The discussions and recommendations on these issues are on the following working group reports.

CERT MANAGEMENT/COST EFFECTIVENESS/DOD 5000.40 WORKING GROUP SUMMARY

1. SUMMARY OF WORKING GROUP ACTIVITIES

The CERT Management/Cost Effectiveness/DoD Directive 5000.40 Working Group was chaired by Col. Thomas Musson of the Office of the Under-Secretary of Defense with Mr. Robert Hancock of the Vought Corporation as co-chairman. Working group participants are identified in the list of attendees (See Attachment A). The format followed by the working group was to begin with an open discussion leading to the definition of specific issues for detailed review by the group. Five issues were identified relating to:

(1) CERT education/explanation.
(2) Transition from concept to application.
(3) Experience to date with DoD Directive 5000.40 testing guidance.
(4) Need for environmental hardware engineers.
(5) Identification of CERT benefits.

These topics were addressed by the group to varying degrees based on relative importance as perceived by the group. Emphasis was placed on cost effectiveness (in Item 5) which was broken down into elements for detailed assessment by individual members, followed by overall group review.

2. GENERAL DISCUSSIONS

Working group activities commenced with a general discussion of objectives and concerns involving all participants. The intent was to surface specific issues for detailed review in subsequent discussions. The following paragraphs summarize the general discussion in various areas. The statements therein represent opinions and comments expressed by individual participants as opposed to group concensus.

2.1 Need to Inform Decision Makers

Currently decision makers do not have the information they need relative to whether and how to implement CERT. Communication to program managers is particularly essential. The current situation is such that program managers can be motivated to hide failures rather than find them. They need to get the message that realistic reliability testing can keep their program "out of the newspapers" at a later date by uncovering problems early. We need to legitimize failures and motivate the program manager to plan tests with the specific objective of uncovering problems. Reliability can no longer be viewed as a wicket to be passed through; the emphasis in reliability testing should be realism. The communication problem should be addressed for all three services.

2.2 Definition of CERT

The question arose concerning how the working group should be defining CERT for its purposes. For example, is any test that involves stresses, CERT? CERT might be better perceived as a process for improving and measuring reliability. Both the Air Force Flight Dynamics Laboratory and the Navy Pacific Missile Test Center are doing the right thing in this regard - - that is, thinking the problem through. In the interest of not becoming a cult, it might be better not to specifically define CERT. Past mistakes relative to over disciplining the system acquisition process should not be repeated. It would be better to refer to CERT as an improved reliability test approach and identify a menu of items for potential inclusion; such as Test-Analyze-Fix (TAF), mission profile testing, etc.

2.3 When and at What Level of Assembly

Most testing to date has been performed on equipment already in the inventory. Can CERT testing be moved up to an earlier phase in the system development cycle? Similarly, there is the question of at what levels of assembly should the various types of test be applied. A sound approach may

be to perform parts screening and individual stress testing early to weed out material defects, proceed to TAF testing at higher assembly levels to uncover design deficiencies and quality problems, and then perform mission profile testing for reliability measurement and/or qualification for the major programs. One industry observation is that prior programs have had CERT-type tests removed at the last minute - - probably due to funding concerns. Therefore, CERT must be institutionalized in the system specification/program documentation.

2.4 Transition from Concept to Application

The need exists to identify specific activities which will help to institutionalize CERT into the system acquisition process. The relative advantages and disadvantages of the top-down versus the bottom-up approach should be considered. The bottom-up approach has the advantage that the SPO can get the CERT requirement into an RFP much easier than can be achieved through the Air Force Regulation route. However, it will be very difficult for the workshop to achieve this objective by going directly to program managers.

3. WORKING GROUP ISSUES

Following the general discussion, five issues were identified for working group review:

(1) CERT education/explanation.
(2) Transition from concept to application.
(3) Experience to date with DoD Directive 5000.40 testing guidance.
(4) Need for environmental hardware engineers.
(5) Identification of CERT benefits.

The last three issues were defined for the working group in advance and the first two emerged in the general discussion. The chairman determined that Issue 5 merited the highest degree of attention in light of its numerous aspects and its relevance to Issues 1 and 2. The approach taken was to break Issue 2 down in terms of the types of reliability tests at different phases of the system life-cycle as follows:

- Environmental test methods (MIL-STD-810B)
- Reliability development growth test
- Reliability qualification test
- DT&E/ OT&E supplemental testing
- Testing for source selection
- Production verification test
- Testing to identify field problems (RTOK)
- Maintenance support testing
- Environmental stress screening.

For each of these items a working group member was tasked to prepare a summary on the purpose and role of the test, advantages relative to previous approaches, and recommendations.

4. ISSUE REVIEW AND RECOMMENDATIONS

4.1 CERT Education/Explanation

The question addressed was how to package the output of the workshop for senior levels in government and industry. The concensus recommendation was that, in addition to the workshop proceedings, the sponsors should assemble a quality presentation, approximately 45 minutes in length. Various workshop members can take intitiatives to assure that the presentation will be seen by the appropriate organizations. AFSC Headquarters and the Joint Logistics Commanders were identified as primary targets for the briefing. It was also recommended that the presentation be considered for the Armament and Avionics Planning Conference, National Aerospace and Electronics Conference (NAECON), and the Reliability and Maintainability Symposium. Appropriate periodicals, such as Aviation Week and the Defense Management Journal, should also be informed of workshop activities. Preparation of a videotape of the presentation was recommended. An associated recommendation is to interface with appropriate educational institutions, including the Air Force Institute of Technology and Defense Systems Management College.

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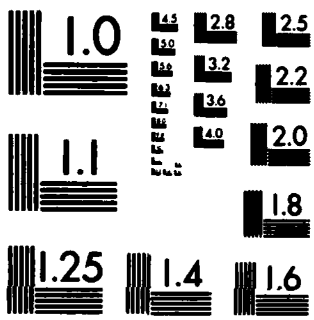

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

4.2 Transition from Concept to Application

The question addressed was to identify the most effective means of implementing the use of combined environments testing in acquisition and modification programs across the Department of Defense. History has been that this type of testing has been performed on an exception basis. The group recommends that DoD issue a letter to each of the three services requesting identification of a focal point and that DoD acquisition policy directives be reviewed in view of reliability test policy directed in DoD Directive 5000.40 and the recent Carlucci study. A secondary recommendation, to support the bottom-up institutionalization approach, is that data from programs successfully implementing the combined environments testing concepts (e.g. Omega, Common Strategic Doppler, Sparrow Missile) be evaluated and consolidated.

4.3 DoD Directive 5000.40 Implementation Experience

DoD Directive 5000.40 was formally issued about eleven months ago, but has been around over three years. The issue addressed was to identify insights which have been learned that could be used to help any revision of the directive. The panel chairman addressed this issue. In view of the recent initiatives launched by Deputy Secretary of Defense Carlucci to revise the entire system acquisition process, the status of Directive 5000.40 and other acquisition directives are currently uncertain. Therefore, it was not deemed to be beneficial for the working group to make firm recommendations relative to this issue.

4.4 Need for Environmental Hardware Engineers

The question addressed was whether a new technical discipline called Environmental Hardware Engineering needs to emerge to support the increased emphasis on environmentally based tests including: engineering development, performance tests, reliability, stress screening, growth, formal environmental qualification and any other tests performed in the acquisition process. Individuals skilled in this discipline shall be able to use existing hardware design techniques, results of operational analyses, and knowledge of testing techniques to design and/or identify which environmentally based tests should

be included in an acquisition program. Furthermore, they should be able to determine the appropriate test conditions and criteria. This subject received minimal attention by the working group due to time spent on other issues and no firm recommendations where developed.

4.5 Identification of CERT Benefits

4.5.1 MIL-STD-810B Environmental Test Methods

Alan Burkhard of the Air Force Wright Aeronautical Laboratories (AFWAL) presented this subject to the panel. The purpose of MIL-STD-810B testing is to verify the ability of an equipment design to function under (and/or withstand) the most severe environmental stresses to be encountered throughout its entire life-cycle. The role of the tests is to identify design defects and to determine contractual compliance. The current testing approach is to subject a single equipment item to a single environmental test. Typically, no single equipment is exposed to all anticipated environmental stresses. An improved approach, based on CERT concepts, would be to combine environmental stresses when economically feasible. The potential benefits of this improved approach lie in a reduction of the number of test and equipment items required for testing.

4.5.2 Reliability Development Growth Testing

Col. Ben Swett of the Defense Industrial Supply Center (DISC) presented this subject to the panel. The purpose of these tests is to detect all possible design deficiencies as early as possible, and at as low a level of assembly as possible, during the full-scale engineering development phase. The old development testing approach relative to reliability growth was usually fragmented and often was not performed at all. This resulted in deficiencies not being identified until system-level development tests or operational tests. A recommended improved approach would be to follow environmental stress screening and MIL-STD-810B tests with a mission profile Test-Analyze-And-Fix (TAAF) program at the equipment level prior to the development test/operational test at the system level. The potential benefits of this improved approach lie in the avoidance of subsequent cost and schedule delays due to latent defects and a reduced risk of failing qualification tests.

4.5.3 Reliability Qualification Test

William Silver of Westinghouse presented this subject to the panel. The purpose of the reliability qualification test is to measure the reliability of a test article to demonstrate compliance with contractual reliability requirements. The old approach often results in testing to an environmental profile which was not representative of operational conditions. The result, in these circumstances, is a biased measured reliability which is not useful for logistics and operational planning purposes. The recommended improved approach is to establish the qualification test procedures in accordance with the priorities established in MIL-STD-781C, Appendix B and, in particular, to conduct a TAAF Program preceding a CERT mission profile qualification test. The potential benefits of this approach lie in the acquisition through the qualification test, of a realistic measure of field reliability and, if TAAF is conducted prior to the formal qualification, in a higher probability of passing the test.

4.5.4 Supplementary Testing

Major James Horkovich of the Air Force Test and Evaluation Center (AFTEC) presented this subject to the panel. The purpose of this testing is to supplement flight and operational test/evaluation programs with combined environments testing. Such supplementary testing is not generally utilized under the old approach resulting in flight/field test program delays while fixes to test hardware are incorporated. The new approach would use combined environments testing to identify problems before they cause flight failures. It is especially recommended when there is emphasis on currency in the development cycle. The benefits of supplementary testing lie in the more efficient utilization of test resources, and in the ability to obtain more reliability and maintainability data within a set period of time, even in the presence of weather and other flight delays.

4.5.5 Source Selection

Robert Gates of The Analytic Sciences Corporation (TASC) presented this subject to the panel. The role of CERT in support of the source selection process is to provide evaluators with meaningful reliability data for

purposes of comparing competing system designs. Under the old approach, the evaluators had only reliability predictions (i.e. from MIL-HDBK-217), or whatever data was submitted in the proposals, on which to base their comparisons. The improved approach would be to perform CERT (at government or independent facilities) on competing pre-production prototypes prior to the source selection. The potential benefits of this approach lie in the availability to evaluators of realistic reliability predictions, thus making reliability a meaningful comparison factor. These predictions can also be utilized to develop more realistic life-cycle cost comparisons of the competing designs.

4.5.6 Production Verification Testing (PVT)

Brent Meeker of the Pacific Missile Test Center (PMTC) presented this subject to the panel. The purpose of PVT is to assure that the quality of equipment undergoing a long period of production is not degraded relative to that demonstrated during development. The major PVT element relating to reliability is the Production Reliability Acceptance Test (PRAT) called out in MIL-STD-785B as Task 309. The old PVT approach was to base an accept/reject decision on a very short test of a small shape of production units. The tests were often destructive in nature. The improved approach would be to use realistic, and therefore non-destructive, test environments and to extend the test length so that MTBF (rather than pass/fail) can be measured. The test results can then be fed back into the failure analysis and corrective action process. The benefits of a CERT-based PVT lie in the improved field reliability resulting from this feedback and better reliability measures for logistics and operational planning purposes.

4.5.7 Field Problems

Alan Burkhard of AFWAL presented this subject to the panel. The subject relates to the use of a CERT mission profile test to identify intermittent or volatile failures that can be observed only when the equipment is subjected to a particular stress state. The current testing approach generally will subject the equipment to only a single environmental stress, based on a prejudgement as to which stress is important. The improved

approach, which has been utilized by Newark AFS on an Inertial Measurement Unit, would use a mission profile test to identify if the failure is induced by stresses that occur during operational use. The benefits of this approach lie in the rapid determination as to whether the intermittent or volatile problem is environmentally induced, as opposed to a result of software, test equipment, technical orders, or personnel errors.

4.5.8 CERT for Maintenance Support

Maj. Robert Gass of Air Force Systems Command (AFSC) presented this subject to the panel. This subject relates to the establishment of a combined environments test facility at a depot for testing returned units and repaired units prior to return to the field. The current depot test approach often results in many units which retest-OK being returned to the pipeline. The improved approach would test such units in the CET facility after they pass the normal checkout procedures. The facility could also be used after all repair activities are completed as a screen to verify the "goodness" of the repair. The benefits of this approach lie in the potential savings in logistics cost since it is less costly to repair problems at depot than in the field, and in improved spares sufficiency by keeping RTOKs out of the pipeline.

4.5.9 Environmental Stress Screening (ESS)

Richard Baker of Screening Systems, Inc. presented this subject to the panel. The purpose of ESS is to uncover latent equipment manufacturing defects. The old approach to ESS has been somewhat inconsistent and fragmented relative to environmental stresses and has been applied primarily at the parts level. The improved approach would be to use a combined environments test for ESS and perform the test at all pertinent levels of assembly (it may not be always oractical at the system level). Furthermore, the ESS testing should be performed on both test and production hardware. The benefits of this improved approach lie in improved quality control, rapid problem identification and correction, and higher initial reliability for both prototype systems for developmental testing and operational systems.

ATTACHMENT A - ATTENDEES

CERT MANAGEMENT/COST EFFECTIVENESS/DOD 5000.40 WORKING GROUP

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Slide One

CERT MGT/COST EFFECTIVENESS/5000.40 WORKING GROUP

APPROACH

- GENERAL DISCUSSION
- DEFINITION OF ISSUES
- REVIEW AND RECOMMENDATIONS

Slide Two

ISSUES DEFINED

- NEED FOR HARDWARE ENVIRONMENTAL ENGINEERS
- IDENTIFICATION OF BENEFITS
- 5000.40 IMPLEMENTATION EXPERIENCE
- TRANSITION: CONCEPT TO PRACTICE
- EDUCATION/EXPLANATION

Slide Three

BENEFITS

ACTIVITY	BENEFITS	RECOMMENDATIONS
MIL-STD-810B METHODS	FEWER TEST SPECIMENS	COMBINE ENVIRONMENTS
DEV. TESTING	AVOID COST & SCHEDULE DELAYS	SPECIFY FOR ALL FSED PROGRAMS
R-QUAL	MORE REALISTIC MEASURES OF R	USE MIL-STD-781C-PR 1
SUPPLEMENTAL TESTING	OPTIMAL USE OF TEST RESOURCES	EMPLOY CERT TO SUPPLEMENT FLIGHT FIELD TESTS
SOURCE SELECTION	MAKES R A MEANINGFUL COMPARISON FACTOR	CERT FOR COMPETING DESIGNS
PROD. VERIFICATION TEST	MEANINGFUL FEEDBACK TO PRODUCTION	DIRECT CONSIDERATION IN TEMP
FIELD PROBLEMS	PROBLEM (RTOK) IDENTIFICATION	CERT TO IDENTIFY VOLATILE FAILURE
MAINT. SUPPORT	FIND PROBLEM AT DEPOT, NOT FIELD	CET CAPABILITY AT DEPOT
STRESS SCREENING	HIGHER INITIAL R (TEST & OP)	USE ESS FOR ALL DELIVERABLE HARDWARE

TECHNICAL APPLICATIONS WORKING GROUP SUMMARY

A. ISSUE NR. 1:

What are the potential uses of CERT? (Initial Issue)
What is reliability testing? (Issue evolved from initial issue)

Discussion:

A lengthy discussion followed on what reliability testing is and how it fits into the overall hardware acquisition process. If the broad sense of the term is used to mean that failure data is available for hardware improvement or characterization, then the following tests may be considered as reliability tests:

- MTBF demonstration
- Design verification
- Reliability growth
- Identification of failure modes
- Screening
- Design margin identification
- Qualification
- Mission profile
- Production acceptance
- Flight worthiness
- Time acceleration
- Platform compatibility work verification/recertification
- Dormant reliability
- Workmanship

In terms of reliability as a function, it should be considered an engineering function as well as a statistical function and, therefore, it is part of the equipment and should be part of the design effort rather than relegated to a specific organizational function or department.

The contributions of CERT as part of the reliability test process were dealt with in three categories as described in MIL-STD-785B: deficiency disclosure, operational characterization, and contractual characterization. In the case of deficiency disclosure, the critical need was identified for engineering judgement in applying CERT. There was strong reaction against the blanket application of CERT. Both mission profile testing and so-called worst-case testing have potential benefits, however, it is felt that scoring of test results (e.g., measuring

reliability parameters) at this point was inappropriate in order to encourage the contractor to identify and eliminate failure modes.

The potential benefits of CERT were identified as:

1. Schedule compression/cost savings due to test efficiency.
2. Detection of synergistic failure modes (failure modes detected only by the simultaneous application of more than one environmental forcing function).
3. Identification of intermittent performance under environmental stress.
4. Reduced manpower/setup time by testing more than one environment at a time.

The limitations are:

1. Profiling of environmental conditions to simulate representative missions is not appropriate for screening.
2. Scoring information not readily available from reliability engineering tests.
3. Adequate assets (i.e., test sample population) may not be available.
4. Facilities may not be readily available.
5. Possible need for special support/diagnosis equipment.

CERT can also be used for accounting tests. These were considered as those tests used for determining reliability data as an input for estimates of operational readiness, mission success, maintenance manpower cost and logistic support cost. In addition, accounting tests are used to determine compliance with quantitative reliability requirements. It was felt that combined environment testing has been used for a long time (e.g., AGREE testing). It was felt that the primary advantage of CERT for accounting test occurs when the equipment is tested under expected operational conditions and profiles. Under these circumstances, the government can expect a greater likelihood of obtaining a representative characterization of operational performance. However, it was again emphasized

that CERT is not a cookbook and must be based upon thorough engineering analysis of realistic expectations regarding operational use if it is to provide the increased accuracy which is hoped for in predicting reliability.

Recommendations:

1. CERT should not be applied as a blanket methodology
2. CERT should be based upon thorough, realistic engineering analysis
3. CERT is and should be regarded as more than mission profile testing. It is applicable to any situation in which it can improve effectiveness or efficiency.
4. The concept of mission profile testing must be expanded to consider all phases of the hardware life-cycle. Life-cycle profiles should include shipping/transport and storage conditions, when practical, in addition to sortie conditions. If the total life-cycle is not considered, significant stress conditions may be missing from the test program, thus increasing the likeliness of critical hardware deficiencies remaining undetected until operational service.
5. In applying CERT during production screening, it is inefficient and therefore, inappropriate to test using profiles simulating representative operational missions. Significant life-cycle stresses should be considered in designing a screen, but ultimately the only environmental conditions required are those which disclose defects quickly and effectively, regardless of whether or not they simulate mission conditions.

B. ISSUE NR 2:

Should CERT be used in lieu of, or in conjunction with, flight testing?

Discussion:

There was agreement that CERT should not be considered a complete replacement for flight testing or other operational evaluation. However, CERT can play an important role as a pre-flight test design and workmanship screen. The use of a short-run CERT as a ready-for-flight measure to improve flight test hardware reliability could be extremely useful in excluding flight safety of the equipment.

Also, CERT can provide for more efficient use of costly flight test personnel, facilities, equipment and range time, by improving equipment reliability so that planned evaluations can happen when and in the amount of time planned.

The question of the most appropriate level of assembly for CERT application was raised. Discussion centered around examples and experiences in which testing was blind to interface conditions. That is, deficiencies were not found because they resulted from:

a. Separately tested units performing in concert for the first time under environmental extremes.

b. Cable harnesses and wire bundles between equipment being outside of the test scope.

c. Handling and troubleshooting operations at a system level.

It was felt that the greater the level of assembly at which CERT is applied, the less likely that critical deficiencies related to interface conditions will remain undetected in test.

<u>Recommendations:</u>

1. The use of CERT as a quick check of equipment before flight testing and operational evaluation.
2. Should be encouraged to provide flight safety and more efficient use of costly operational test and evaluation facilities and resources.
3. The higher the level of assembly at which CERT is performed, the greater the confidence in the test results as useful indicators of subsequent field performance.

C. <u>ISSUES NR 3:</u>

Should CERT be based on so-called worst-case environmental conditions most likely to occur?

How should CERT be applied for multi-application equipment?

Discussion:

A presentation was made describing the problem of selecting test environments in terms of potential impact on operating and support (O&S) costs. The issue centered around the consequences for choosing the most severe platform environment as the baseline in establishing test environments. Alternatively, what would be the consequence of using composite or most-likely platform profiles?

It was decided that the need to develop tools to evaluate O&S costs and their impact to specific failure modes prohibits the use of platform environments other than most severe as a basis for establishing test environments. Engineering judgement and analysis should be used to assess the impact of corrective action for specific failure modes on reducing total O&S costs across all applications.

Recommendations:

Most severe environment, including the life-cycles of a multiple platform or multiple mission should be used as a baseline in establishing a test environment on design improvement and disclosing deficiencies in order to evaluate failure mechanisms over the expected operational profile. However, engineering judgement must be used to evaluate the incorporation of design changes in terms of cost-effectiveness of O&S cost reduction.

D. ISSUE NR. 4:

What differences, if any, should there be between reliability tests used for operational characterization and compliance characterization?

Discussion:

It was generally felt that representative environmental test profiles should be both types of characterization tests. The test profiles should be based on all significant life-cycle environments, and not limited to sortie conditions. The

point was made that differences in the way the equipment user defined war-time and peace-time needs might result in different environmental profiles being considered representative for operational versus contractual characterization. It was also noted that long-term storage environments are usually not included as part of the test profile because of the large schedule impact and because the characterization of dormant failure modes is too incomplete to allow realistic and predictable time compression.

Recommendations:

1. Representative environmental test profiles, based on anticipated significant life-cycle environmental conditions, should use realistic stresses in appropriate time proportions.

2. Long-term storage does not have to be part of life-cycle test profiles. Although these conditions should be considered, their inclusion should be based upon practicality, anticipated benefits and schedule constraints.

3. User needs should determine which test profiles are considered representative for operational versus contractual reliability characterization. They may differ.

E. ISSUE NR. 5:

Can CERT be used as a substitute for, or in conjunction with, other tests?

Discussion:

The major advantage of CERT is the potential for streamlining the test process. For example, the use of CERT for reliability improvement while also satisfying qualification or other requirements listed as a primary area of combining test objectives.

The example cited in the Wagner/Burkhard paper (page 3.6) presented at this workshop was identified as an excellent demonstration of this potential benefit.

The critical need for test integration in the hardware acquisition was identified as essential to realizing the full potential of CERT. Compartmentalization of program phases (development, qualification, production) was seen as an obstacle to effective test integration.

Recommendations:

1. CERT should be considered as a method to replace test time and save cost in terms of combining test objectives of different program phases (such as qualification, reliability improvement).

2. Integrated test planning will permit the most effective use of CERT as a tool for hardware reliability improvement and characterization.

ATTACHMENTS

The list of participants in the Technical Applications Working Group is included in Attachment A. Copies of the viewgraphs used in the final Feedback Session are included in Attachment B.

ATTACHMENT A - ATTENDEES

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RELIABILITY TESTING

- DISAGREEMENT OVER CONCEPT
- RELIABILITY TESTING FOR ACCOUNTING PURPOSES

  VS

  RELIABILITY ENGINEERING TESTS FOR DEFICIENCY DISCLOSURE
- BOTH TYPES IDENTIFIED AS RELIABILITY TESTS IN MIL-STD-785B

MIL-STD-785B RELIABILITY TESTING

- TEST TYPES - ENGINEERING
  ACCOUNTING

- TEST PURPOSES - DEFICIENCY DISCLOSURE
  OPERATIONAL CHARACTERIZATION
  CONTRACTUAL CHARACTERIZATION

CERT FOR DEFICIENCY DISCLOSURE

- CERT DEFINITION MUST BE AN ENGINEERING TASK
- PERCEIVED AS PRIMARILY AN AVIONICS TEST, BUT IT DOESN'T HAVE TO BE
- BLANKET APPLICATION INAPPROPRIATE
- FORMAL SCORING (OPERATIONAL CHARACTERIZATION) INAPPROPRIATE
- REPRESENTATIVE MISSION-PROFILE TESTS AND SO-CALLED WORST-CASE TESTS BOTH HAVE POTENTIAL BENEFITS

POTENTIAL CERT BENEFITS (DEFICIENCY DISCLOSURE)

- SCHEDULE COMPRESSION (AND ASSOCIATED COST SAVINGS)
- IDENTIFICATION OF SYNERGISTIC FAILURE MODES
- DISCLOSURE OF INTERMITTENT PERFORMANCE UNDER ENVIRONMENTAL STRESS
- REDUCED FACILITY RELATED MANPOWER/ SET-UP TIME
- IMPROVED HARDWARE RELIABILITY FOR ENVIRONMENTAL WORTHINESS TESTS (SUCH AS SAFETY-OF-FLIGHT)

CERT LIMITATIONS

(DEFICIENCY DISCLOSURE)

- CERT BASED UPON TEST PROFILES SIMULATING OPERATIONAL MISSIONS INAPPROPRIATE FOR SCREENING (INEFFICIENT)
- SCORING (OPERATIONAL AND CONTRACTUAL CHARACTERIZATION) INFORMATION NOT READILY AVAILABLE
- ADEQUATE ASSETS (i.e., TEST SAMPLES) MAY NOT EXIST
- CERT FACILITIES MAY NOT BE READILY AVAILABLE:
  A. TEST PROGRAMS 'QUEUED' BECAUSE ALL TESTS IN SAME FACILITY
  B. FACILITIES MAY NOT BE ABLE TO PROVIDE SPECIFIC CERT CONDITIONS
- POSSIBLE NEED FOR SPECIAL SUPPORT/DIAGNOSTIC EQUIPMENT

TEST REALISM

- USE MOST SEVERE PLATFORM AS REPRESENTATIVE, IF IT IS TYPICAL
- USE EXTREME ENVIRONMENTAL CONDITIONS FOR DEFICIENCY DISCLOSURE AND DESIGN IMPROVEMENT
- USE REPRESENTATIVE TEST PROFILES BASED ON LIFE-CYCLE PROFILES FOR OPERATIONAL AND CONTRACTUAL CHARACTERIZATION
- DIFFERENT PROFILES MAY BE REPRESENTATIVE FOR DIFFERENT CHARACTERIZATION GOALS
- THE HIGHER THE LEVEL-OF-ASSEMBLY TESTED, THE GREATER THE CONFIDENCE IN CERT RESULTS

ENGINEERING ANALYSIS AND JUDGEMENT CRITICAL TO SUCCESSFUL CERT!

TWO VIEWS OF CERT

FORCING FUNCTION INTEGRATION	DISCIPLINARY INTEGRATION
(COMBINED ENVIRONMENT)	COMBINED
*	*
	(ENVIRONMENTAL/RELIABILITY)
(RELIABILITY TESTS)	*
	TESTS
[CE*RT]	[C*E/R*T]
THIS VIEW IS TRADITIONAL	THIS VIEW MAY HELP RESOLVE AREAS OF DISAGREEMENT

FACILITIES WORKING GROUP SUMMARY

A. ISSUE:

Would the availability of government-owned and operated CERT facilities for DoD equipment systems be of significant benefit to the government?

B. DISCUSSION:

It was the general consensus of the panel that CERT be applied. The discussion centered on which types of testing is Design Evaluation, TAAF, REL DEMO, Screening, etc. CERT should be used and at whose facilities it should be performed: government laboratories, independent testing laboratories or contractors in-plant facilities.

The definition of CERT accepted by the panel and used as a basis for identifying and applying CERT facilities is the "Caruso" definition:

> "Any laboratory test for hardware reliability improvement or characterization in which environmental forcing functions are applied simultaneously."

There was early general agreement that TAAF was primarily a contractor function and responsibility though instances where it was not being performed at the contractor's facility were cited. Strong emphasis was placed on the importance of stress screening in the manufacturing process. It was accepted by all that it was an important CERT type activity in the manufacturing process.

There was an often repeated discussion on the multiple application of common CERT resources whether they be government owned or industry owned. A strong point made by one of the industrial participants was that the government should not edict the use of government-owned CERT facilities, especially when to do so would increase the costs of performing the CERT evaluations. The consensus of the group is that a "cookbook" approach to CERT should not be applied but rather decisions as to whose and how much CERT should be done, should be based on various factors such as: purpose of the particular CERT, the level of test, existing facilities, the need for objectivity (conform to DoD 5000.40), schedule constraints, etc.

A resource deficiency was identified during the discussions. At present there is no identified organization and process within the government with CERT expertise to perform the function of evaluating contractor CERT plans and programs and to assist the program officers in establishing contractual requirements. It was felt that this is an issue for the CERT Management Panel.

It was concluded that the government needed CERT facilities as well as industry. A distillation of the Facilities Panel's position is presented in the follwing paragraphs.

Factors impacting the decision to develop CERT facilities within the government or at the contractors facility must be examined for each commodity at various phases in the acquisition process. These factors include:

1. Purpose of CERT
   - Engr. Design
   - TAAF
   - Qualification
   - Rel. Demo
   - Screening
   - PATE
2. Level of Test (System vs black-box)
3. Existing facilities
4. Objectivity (DoD 5000.40)
5. Schedule
6. Desirability of source comparison
7. Independent test facility to support competitive development
8. Technical expertise

CERT facility requirements between the government and contractors are determined by the appropriate roles between the government and the producer. These roles are:

1. Government:
   - Develop test techniques
   - Maintain test specification
   - Review/appraise contractor CERT
   - Assess product reliability
     - At DSARC III
     - During production
   - Perform CERT of out-of-production items
   - Assure impartial evaluation of competing contractors.
2. Contractor:
   - Design/Produce/Evaluate System

C. RECOMMENDATIONS:

The recommended facility assignments and requirements to perform these roles are summarized as follows:

1. Government:
   a. Operate facility to conduct development of test techniques/specifications.
   b. Maintain sufficient expertise to assess contractor CERT and assure technology transfer from test development to program effort.
   c. Provide evaluation/correlation of contractor test facilities.
   d. Assess product reliability - from results of Rel Demo and PATE. Test location at independent laboratory/government facility in-plant.
2. Contractor:
   a. Perform CERT screening as element of production process.
   b. Perform TAAF at independent laboratory/government facility/ in-plant depending on program.
   c. Perform reliability demonstration test at independent test lab/government facility/in-plant.

ATTACHMENT A - ATTENDEES

FACILITIES (IN-HOUSE vs INDUSTRY) WORKING GROUP

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MIL-STD-781/APPENDIX B AND MIL-STD-810 WORKING GROUP SUMMARY

A. INTRODUCTION

The MIL-STD-781/MIL-STD-810 Working Group, consisting of 14 attendees (8 government/6 industry)*, met to discuss the differences and similarities between MIL-STD-781/Appendix B and MIL-STD-810. Mr. William Wallace presented an overview of the new MIL-STD-781D draft presently in a coordination cycle. Mr. David Earls presented the MIL-STD-810D proposed draft material which is in final preparation stages for formal coordination by 1 September 1981.

Basically, differences in the two standards were summarized as follows:

1. MIL-STD-781/Appendix B tests consist of up to 4 environments, applied to electronics equipment in relatively long duration tests to obtain reliability (MTBF) information. The environmental conditions in MIL-STD-781 represent those levels which are found for the majority of the time during the life-cycle (not extreme conditions).

2. MIL-STD-810 contains approximately 20 environments, usually applied for short time durations, and represent higher level values associated with particular portions of the life-cycle profile. MIL-STD-810 tests apply to a wide variety of equipment categories, much broader in scope than electronics. MIL-STD-810 tests are conducted to determine if equipment will function and withstand severe environmental conditions to be encountered in service.

A major similarity in the two standards includes the fact that each standard requires life-cycle profiles associated with the equipment to be tested, along with the environmental conditions for all phases of the profile.

B. SUMMARY OF ISSUES

After discussion of the above points of similarity and diversity, the working group proposed the following 4 issues for further consideration.

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* See Attachment A for list of attendees.

The recommendations should be taken in the context that they were developed to present a basis for resolution to be considered further. They should be evaluated in a more deliberate manner, considering more deeply the ramifications of the work effort involved and payoff expected. They are not necessarily a consensus, but are presented for further detailed investigation.

1. ISSUE NR. 1

Life-Cycle Environmental Profiles.

Discussion:

There is a need to provide the methodology and techniques to develop and construct life-cycle environmental profiles. Such profiles are needed to include all phases of the life-cycle, which includes mission, storage, transportation, etc. As recognized in MIL-STD-810 and MIL-STD-781, such profiles will differ between weapon platforms as well as applications on each platform. However, the basic technique, concept and necessary considerations required to develop such profiles are constant (standard).

Given the construction of a life-cycle profile, design requirements as well as test plans can be derived using appropriate portions, environmental conditions and limits of the profile. The environmental stress values (levels, times, rates of change, etc.) associated with the various portions of the profile may be provided from a data base, measurements, estimates, etc.

In this context, the development of a test program whose objective is to characterize reliability (MIL-STD-781) should use appropriate portions of the life-cycle profile as a baseline. MIL-STD-810 provides environmental test methods and procedures covering a broad range of weapon platforms. It also incorporates related guidance and rationale, including development of life-cycle environmental profiles.

Recommendation:

a. MIL-STD-781 and MIL-STD-810 must complement each other, so that there is no conflict. There should be no overlap or redundancy. As an interim or first step, it is recommended that Appendix B of the MIL-STD-781D draft be a basis for developing life-cycle environmental profiles and that the test methods and procedures identified in MIL-STD-781 be compatible (not conflict) with MIL-STD-810 tests. As a longer range action, or second step, environmental life-cycle profile methods/techniques and test methods/procedures should be in MIL-STD-810 (deleted from MIL-STD-781) or life-cycle profile requirements should be in a separate document.

b. MIL-STD-781 and MIL-STD-810 were established for different purposes. The environmental life-cycle profiles, eventually to be centralized in MIL-STD-810, should include all environments which a particular piece of hardware will experience during its life-cycle. MIL-STD-781 should evaluate and select those environments and levels which have a significant impact on long term reliability. The remaining environments and short duration, high level environmental conditions should be subjected to MIL-STD-810 test methods and procedures, as applicable.

2. ISSUE NR. 2

Environmental Data Base.

Discussion:

There is a need for a data base for realistic mission profile environmental data on existing platforms and platforms being designed (e.g., estimated levels). This would be a common data base for use with both 781D and 810D. In order to satisfy the objectives of 781D (i.e., measure MTBF) and

8100 (i.e., verify design adequacy for functional and endurance considerations), data should include average, extreme (e.g., 95th percentile) and accelerated test level algorithms. This data would be put into a document and updated as new platforms come into existence. The advantages of this document are:

a. Such a document would tend to ensure that realistic mission profiles would be used (which is desired by the military) in preference to "Appendix B" type data.

b. Quotes from manufacturers for testing would be for the same tests.

c. Common data would be readily available to procuring agencies and manufacturers.

d. Common design criteria would be assured for the anticipated application during the proposal, and design and development stages.

This document would serve a role similar to that of MIL-HDBK-5 "Fatigue Strength of Aircraft Structural Materials".

Recommendation:

Appropriate military agencies should generate and maintain a readily available document which contains a common environmental data base of existing platforms for use with MIL-STD-781D and MIL-STD-810D.

3. ISSUE NR. 3

Establish Minimun Vibration Level for Retaining Test Effectiveness and Increasing Efficiency for Long Duration Testing (Time Sharing Vibration Facilities).

Discussion:

There is a need to establish a lower threshold cutoff level of vibration, where there is no significant impact on the hardware life, thus allowing high cost vibration test equipment to be shut down or time-shared with other temperature chambers to increase overall cost effectiveness. Alternative techniques may be developed to accelerate only the low level vibration to cut down vibration test time. The MIL-STD-781C version allowed this concept, whereas the MIL-STD-781D draft requires a minimum vibration level to be continuously applied during periods when vibration levels are actually lower than the minimum.

Recommendation:

Delete the requirement to vibrate during the test time that the mission profile vibration level is equal to or less than 0.001 g^2/Hz.

4. ISSUE NR. 4

Research and Development Plan for MIL-STD-781 and MIL-STD-810

Discussion:

When MIL-STD-781 and MIL-STD-810 are undergoing the revision process, it is common to observe gaps in needed data or technical knowledge. It is recognized that more research and development effort is needed to provide the test capability desired and required for effective advancement in the standard requirements. Examples are: lack of specific platform data; need for accelerated test techniques, chamber simulation techniques, failure distribution prediction, intrinsically high MTBF equipment test techniques; and mechanical equipment reliability test techniques.

Recommendation:

Establish a five-year research and development plan to obtain and evaluate improved methods, procedures, techniques; gather and evaluate profile and platform data, etc.

ATTACHMENT A - ATTENDEES

MIL-STD-781/APPENDIX B & MIL-STD-810 WORKING GROUP

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